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Macroeconomic policy lessons for Greece

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Abstract

This paper studies the Greek economy in the aftermath of the 2007-8 global crisis looking for barriers to, and engines of, growth. We use a micro-founded macroeconomic model calibrated to Greece. We first study the years of the debt crisis between 2008 and 2016 and then the recent covid-19 pandemic. Departing from 2008, our simulations show that the adopted economic adjustment program (the fiscal austerity mix combined with the fiscal and monetary assistance provided by the EU, ECB and IMF), jointly with the observed deterioration in institutional quality (the degree of protection of property rights) can explain most (around 23% of GDP) of the cumulative loss in GDP in the data (around 26% of GDP) between 2008 and 2016. In particular, the economic adjustment program can explain a fall of around 13%, while the deterioration in property rights accounts for another 10%. Counterfactual simulations, on the other hand, show that this loss could have been around 10% only, if the country had followed a different fiscal policy mix; if the degree of product marker liberalization was closer to that in the core euro zone countries; and, above all, if institutional quality in Greece had simply remained at its pre-crisis level. On the other hand, we show that, in the absence of the official fiscal bailouts, the depression would be much deeper, while the accommodative role played by the quantitative policies of the ECB has been vital to the Greek economy. Finally, departing from 2019, we quantify the impact of the covid-19 pandemic under various policy scenaria. A loss of around 8.5% of GDP and a sharp jump of public debt seem to be unavoidable during 2020 but, like in the case of the debt crisis, the duration of the new crisis depends crucially on the policy mix chosen.

JEL classification: O4, H6, E02.

Keywords: Growth, macroeconomic policy, institutions.

1 Introduction

Among the euro zone (EZ) periphery countries hit by the global financial crisis of 2007-8, Greece experienced the worst decline and the biggest need for international support.[1] Between 2008 and 2016, Greece lost more than one fourth of its GDP. It also had to rely on a number of official or unofficial programs of financial assistance provided in various forms by the EU, the ECB and the IMF; only the three official fiscal bailouts between 2010 and 2015 amounted to around 290 billion euros. Although GDP growth managed to rebound in 2017, the recovery was fragile (driven mainly by net exports and private consumption) even before the eruption of the new economic crisis caused by the covid-19 pandemic in early 2020. For instance, at the end of 2019, private investment remained at around 11% of GDP only, public debt was around 175% of GDP, external liabilities were around 140% of GDP with the current account still in deficit, unemployment was around 17% and, perhaps more importantly, Greece scored poorly in institutional quality vis-à-vis other EU and OECD countries.[2] Besides, as part of the various bailout programs, around 70% of Greek public debt is owned by public institutions of the EU and the ECB.

Aim of this paper The aim of this paper is fourfold. First, we search for the drivers of the Greek debt crisis. This includes driving forces and propagation mechanisms through which the driving forces shaped equilibrium outcomes and in particular the big output loss between 2008 and 2016. Second, we conduct a decomposion exercise to quantify the relative contribution of various driving forces, as they are in the data, to this output loss. Third, building upon the first two steps, we search for counter-factual scenaria that could have possibly given better outcomes between 2008 and the covid-19 pandemic. Fourth, we study what can happen from now on given the new crisis triggered by the covid-19 outbreak. Putting all this together, our aim is to identify the barriers to, and the engines of, growth. This helps us to draw some macroeconomic policy lessons that could be useful in the future. We also study distributional implications.

[1] For the Greek crisis, see e.g. Sinn (2014, 2015), Ioannides and Pissarides (2015), De Grauwe (2016), Alesina et al. (2019, chapter 8), Brunnermeier and Reis (2019) and Alogoskoufis (2019). For formal models, see e.g. Arellano and Bai (2016), Gourinchas et al. (2017), Papageorgiou and Vourvachaki (2017), Economides et al. (2017), Glomm et al. (2018), Dellas et al. (2018) and Chodorow-Reich et al. (2019). See also the papers in the volumes edited by Meghir et al. (2017) and Bournakis et al. (2017). See below for details and how our work differs.

[2] In Greece, weak institutions are captured by various indices measuring the poor enforcement of the law, vandalism and violence, an inefficient public administration, a labyrinth of bureaucracy, a slow judicial system, laws and regulations that limit competition, tax evasion, poor education (PISA) scores, etc. For institutional quality in Greece relative to other countries, see e.g. Angelopoulos et al. (2009), Masuch et al. (2018), Afonso and Kazemi (2016), Kollintzas et al. (2018) and Christou et al. (2020). See below for further details.

A brief recollection of events To place our work in context, we need to recall the key events in Greece over the euro period. The Greek debt crisis should not have come as a surprise; it had all the symptoms of a typical international crisis (see e.g. Lorenzoni (2014)). Greece was already in imbalance when the global financial crisis erupted in 2007-8. From the late 1990s to 2008, the country enjoyed an exceptional economic boom and declining unemployment. But this was driven by a big rise in private demand and pro-cyclical fiscal policies, both of which were financed by borrowing from optimistic banks in Greece and Northern Europe. The demand-driven boom led to accumulation of large private, public and external debts. It also led to rises in wages, prices and unit labor costs and hence to losses in competitiveness. In addition, and perhaps this went unnoticed, Greece displayed a big asymmetry in institutional quality (as described above) relative to its EU partners. Then, in 2009, amid an unfavorable environment (the "sudden" recognition of the above imbalances, unpleasant news about the country's public finances, big riots in Athens in December 2008 combined with political polarization, the release of reports by the European Commission and rating agencies expressing fears of sovereign insolvency, etc), confidence was undermined, expectations were reversed, GDP collapsed, debts-to-GDP exploded, and all this became a vicious cycle. Greece, along with Ireland and Portugal, was shut out from private capital markets and the Greek government had to resort to its first official fiscal bailout provided by the EU and the IMF in early 2010. Nevertheless, the fear of default rose again, insolvency was admitted by all and, in 2012, the Greek government defaulted on its bonds held by private creditors. But again this was not enough. Greece had to receive two more official fiscal rescue loans provided by other EU states, EU institutions (EFSF, EFSM, ESM) and the IMF in 2012 and 2015. At the same time, and this has been since the very beginning of the global financial crisis, the ECB provided a plethora of supportive quantitative, or balance-sheet, policies (e.g. direct or indirect intervention in the market for Greek government bonds; the support of private banks through a full allotment lending policy, the relaxation of collateral requirements and the provision of ELA; the issuance of cross-border liquidity that compensated for abrupt private capital inflows and known as *TARGET2* liabilities; etc). All this complex financial (fiscal and monetary) assistance was offered at much more favorable terms than markets would have imposed on Greece. On the other hand, it was conditioned on a severe fiscal austerity plan monitored by the EC, the ECB and the IMF. Although the real motives behind the financial assistance, as well as the rationale of severe fiscal austerity, have been lively debated (see e.g. Alesina et al (2019, chapter 8)), this so-called Economic Adjustment Program, combining austerity and assistance, enabled Greece to remain in the euro area. However, fiscal austerity and economic depression, fuelled by political polarization and populism, were associated with a further worsening of institutional quality. The latter is reflected into indices measuring, for example, the rule of law, regulatory quality, and political instability and violence, which show a sharp deteriorarion during the debt crisis years. Notably, these are the indices typically used to construct measures of the degree of protection of property rights and, as is widely recognized, property rights shape incentives and are fundamental drivers of sustainable growth.[3] Finally, after a difficult decade, Greece exited its Economic Adjustment Program in August 2018 but, as said above, its moderate recovery path that started in 2017 has been abruptly disrupted by the pandemic shock in early 2020.

Our model Our model will embed most of the above distinct features of the Greek economy. The vehicle of analysis is a medium-scale micro-founded macroeconomic model of a small open economy participating in a currency union. In addition to a number of real and nominal frictions commonly used by the quantitative macroeconomic literature, the model incorporates - in an attempt to mimic the Greek case - a rather detailed public sector including public employees as a separate income class, problems of institutional quality in the form of ill-defined property rights that trigger anti-social activities, and, during the debt crisis, international financial assistance combined with fiscal austerity. To understand better the menu of macro policy instruments used, we model separately the Treasury (fiscal authority) and the national central bank participating in the Eurosystem (monetary authority). In other words, the model incorporates the main ingredients of the Economic Adjustment Program as described above, namely, fiscal austerity combined with international financial assistance, where the latter includes the official fiscal bailouts as well as balance-sheet, or quantitative, monetary policies by the Eurosystem. The revenue from the official fiscal bailouts make up for the loss of government revenue from being shut out from private capital markets and this happens at non-market interest rates. At the same time, financial frictions (as in Curdia and Woodford (2010, 2011)), as well as the issuance of *TARGET2* liabilities as part of the monetary base of the national central bank (see Sinn (2014) and Whelan (2014, 2017)), provide the channels through which quantitative, or balance sheet, monetary policies, as allowed by the ECB, can have real effects and thus - like the official fiscal bailouts - "alleviate the fiscal burden" (see Reis (2017)). A more detailed description of our model can be found in subsection 2.1 below before we present the formal model. The model is solved numerically distinguishing two sub-periods: the years of the debt crisis between 2008 and 2019, and the new era marked by the pandemic shock in early 2020.

Main results for the sovereign debt crisis Our simulations show that the Economic Adjustment Program (namely, the fiscal austerity mix

[3] For the key importance of property rights among other measures of institutional quality, see e.g. Hall and Jones (1999), Grossman (2001), Rodrik (2003), Dixit (2004), Acemoglu (2009, chapter 4), Besley and Persson (2009), Besley and Ghatak (2010), Acemoglu and Robinson (2019) and many others.

combined with the official fiscal bailouts and the various types of monetary accommodation provided by the ES), jointly with developments in institutional quality (specifically, the deterioration of protection of property rights), can account for most of the cumulative loss in GDP between 2008 and 2016. In particular, departing from 2008, when we feed our model with the Economic Adjustment Program and an index of property rights, both as they are recorded in the data, the model, via its propagation mechanisms, produces around 23% fall in GDP between 2008 and 2016 as compared to around 26% in the data. The Economic Adjustment Program accounts for 13% and the deterioration in property rights adds another 10%.

On the other hand, counterfactual scenarios during the debt crisis imply the following. First, things could have been much worse. Despite the conflicting views about the content of the bail-out program, especially regarding its fiscal austerity preconditions, our numerical simulations imply that financial assistance (provided by other EU counties and institutions, the ECB and the IMF) has helped the Greek economy to avoid the worst. For instance, if the fiscal needs were financed by, say, higher income taxes rather than by the three official fiscal bailouts, the loss in output would have been tremendous, other things equal. Also, even if one is willing to make the unrealistic assumption that the Greek government were able to keep selling its bonds to the private market, the high market interest rates it would have to pay would have led to a bigger output loss than that in the data. Besides, when we make the assumption that the ECB did not follow an accommodative policy towards Greece, the model ceases to exhibit a (stable) solution implying (to the extent that one trusts our model) that this scenario would be nonfeasible, other things equal. Second, things could also have been better. The output loss could have been significantly smaller if some things had been done slightly differently. In particular, the output loss during 2008 and 2016 could have been around 10% only (always relative to the departure year of 2008), if the country had followed an alternative fiscal policy mix (for example, a cut in income taxes, or an increase in public investment, both financed by a cut in tranfer payments), if reforms in the product market had been adopted and implemented in a faster and/or more effective way so as the degree of product market liberalization to get closer to that in the core EZ countries; and, above all, if institutional quality had not deteriorated since 2008 but had simply remained at its pre-crisis level. It has to be emphasized that improvements in these areas did not have to be in the area of fantasy; in our counterfactuals, we assume small changes vis-a-vis the values in the data. That is, small changes could have made things much better.

Main predictions for the new pandemic crisis We use the model to quantify the impact of the recent covid-19 pandemic on the Greek economy under different actual and hypothetical scenaria. Following Eichenbaum et al (2020), we model the pandemic shock as a temporary adverse labour supply shock. This mimics the effects of the necessitated containment measures on labor supply. Departing from the year 2019, and assuming a rather moderate value for the adverse labor supply shock that lasts during 2020 only, our simulations show that in 2020, and in the fictional case of no policy reaction, the Greek economy could suffer an output loss of around 12% relative to 2019 and public debt to GDP could jump to more than 220%. This shows the big vulnerability of the Greek economy to supply shocks even of relatively small magnitude. Policy responses, on the other hand, can mitigate the economic damage. For example, responding with higher public spending and lower taxes, as the Greek government has already done or has announed to do, can make the recession milder (the output loss can be around 8.5% in 2020) and the rise in public debt smaller (it could be around 214%). The same simulations show that the expected financial assistance from the EU via the Recovery Fund (around 32 billion euros for Greece) can seriously help the Greek economy but this depends crucially on the way it is used. If it is used, for example, to finance public investment, it will limit the output loss to around 6.5% in 2020 and will also put the country on a sustaibale path with public debt falling to around 168.5% in the coming years thanks to economic growth. If, on the other hand, it becomes a common pool for rent seeking, it will be completely wasted (it will be as if the country has received zero aid from the EU) and the country will be trapped in a bad equilibrium in the coming years. Product market liberalization and developments in institutional quality will also be crucial, as they have been during the debt crisis in the 2010s.

Related literature and how we differ As already mentioned, there has been a rich literature on the Greek debt crisis. Papers close to ours, which have also used micro-founded macroeconomic models, include Arellano and Bai (2016), Gourinchas et al. (2017), Papageorgiou and Vourvachaki (2017), Economides et al. (2017), Glomm et al. (2018), Dellas et al. (2018) and Chodorow-Reich et al. (2019). A common finding of most of these papers, which is also a result shared by our work, is that roughly half of the loss in output between 2008 and 2016 is explained by the fiscal austeriry package adopted.

Our work enriches this literature along several dimensions. One key difference is the way we model economic policy. Here, we take a more balanced view by taking into account, not only the costs of fiscal austerity as the above papers have done, but also the role, and the potential benefits, of international financial assistance, where the latter has been both fiscal (fiscal bailouts) and monetary (ECB support) as well as both explicit (e.g. official rescue programs) and implicit (e.g. *TARGET2* liabilities). We do so because one cannot study fiscal austerity without taking into account the other side of the coin which is international financial assistance; as said, the former was the precondition for the latter in the economic adjustment program agreed between Greece and its creditors. We also study the role of the deterioration in institutional quality that occured at the same time and has been triggered by the fiscal austerity measures (and further fuelled by populism from several political sides). Another difference is that several of the above papers, especially Gourinchas et al. (2017), Economides et al. (2017) and Chodorow-Reich et al. (2019), employ a large menu of shocks to explain the crisis, including shocks to TFP, to interest rates on public debt, to default rates, to banks' funding costs, etc. Here, by contrast, most of these variables are endogenously determined. In our paper, when we study the debt crisis, there are two driving forces only (the time-paths of the economic adjustment program and an index of institutional quality, both as recorded in the data), and then the propagation mechanisms of our model provide the channels through which these two driving forces shape macroeconomic and distributional outcomes. For example, to the extent that weak property rights distort private incentives leading to resource misallocation, this distortion shows up as an adverse productivity shock endogenizing the TFP.[4]

Putting all this together, despite a lively debate on the role of financial assistance and institutional quality in policy circles, there have not been theoretical general equilibrium models tailored to study these issues in a unified framework; our paper fills this gap by developing such a model and uses it to quantitatively evaluate their effects. Finally, in terms of findings, we add some new results to those of the literature. For example, we show what would have happened without financial aid from the EU and ECB. We also show that the resource misallocation and output loss, caused by the further deterioration of property rights and the fear of predation since the end of 2008, are particularly large.

But our work is more than a country study. We also contribute to the literature on the nexus among fiscal, public finance and balance-sheet, or quantitative, monetary policies. And we do so in the context of an open economy being a member of a currency union like the EZ. Most of the related papers, reviewed in subsection 2.6 below, have studied this debated nexus in the context of a closed economy, mainly the US. On the other hand, the models used by the ECB have focused on the link between private banks and the ECB staying away from fiscal financing needs (see e.g. Coenen et al. (2018)). Here, by contrast, building on this literature, as well as on the work of Reis (2013, 2017) and Sinn (2014), we study how balance sheet monetary policies can affect fiscal and country resources in a model that exhibits the

[4]The TFP measures the efficiency with which resources are used in production (see e.g. Prescott (2002) and Restuccia and Rogerson (2013)). As is widely acknowledged, differences in TFP are an important factor in accounting for differences in incomes across countries (see e.g. Prescott (2002)). But it is also acknowledged that TFP is endogenous at macro level being determined, for instance, by tax policies and institutions that shape the risks of expropriation. In our model, weak institutions lead to resource misallocation and this determines the "effective" TFP.

key features of the Eurosystem. We show that the role of the ECB in the Greek debt crisis was vital.

Layout The rest of the paper is organized as follows. The model is in section 2. Parameterization, data and the solution for the year 2008 are in section 3. Departing from this solution, section 4 presents positive results over 2008-2019, while counterfactuals are in section 5. Section 6 models the recent covid-19 pandemic and its economic impact on the Greek macroeconomy. Section 7 closes the paper. An appendix contains algebraic details; this appendix is separately submitted.

2 A macroeconomic model for Greece

In this section, we construct a micro-founded macroeconomic model for the Greek economy during the euro period. We start with an informal description of the model.

2.1 Informal description of the model

Although we cannot include all details and capture the complexity of reality as sketched in the previous section and further discussed in subsection 3.2 below, we will at least try to construct a model that embeds the key features of the Greek economy. To do so, we add a number of frictions to a standard small open economy model. These frictions are of two categories. The first category includes real and nominal frictions commonly used by the quantitative macroeconomic literature (see e.g. Uribe and Schmitt-Grohe (2017)). The second category includes Greek-specific features. The commonly used frictions include various types of adjustment costs, debt-elastic interest rates when the country borrows from abroad, imperfect competition, nominal rigidities, etc. The Greek-specific features include a relatively detailed public sector, problems of institutional quality and, since the beginning of the sovereign debt crisis in 2009, international financial assistance combined with fiscal austerity.

In what follows, we briefly introduce the building blocks of the model.

Households There are three distinct types of households, called capital owners, workers and public employees.[5] Capital owners are the economy's stockholders; they own private firms and banks, receive their profits and participate in the international financial market.[6] Private workers work in private firms. Public employees work in state firms. Both workers and public employees can keep deposits at private banks acting as savers. All types of households consume a domestic and a foreign imported good, receive income

[5] Typically, some type of agent heterogeneity is necessary if we want to have savers and borrowers and different interest rates in equilbrium (see below for references and details). This will also allow us to study distributional implications.

[6] See e.g. Lansing (2015) for concentrated capital ownership of this type.

from different types of work, hold currency and are engaged in rent-seeking activities (the latter are discussed below). The three types of households are modeled in subsection 2.2.

Private firms The domestic final good is produced by final good firms that act competitively using differentiated intermediate goods. The latter are produced by intermediate goods firms which act monopolistically à la Dixit-Stiglitz and face nominal rigidities à la Rotemberg. Intermediate goods firms choose labor, capital and imported goods and also make use of productivity-enhancing public goods/services that enter the private production function as an externality. They finance their capital accumulation by retained earnings, by issuance of shares, which are bought by capital owners, and by loans from private banks. There are also capital good firms that produce the capital demanded by intermediate goods firms. Any profits generated by private firms are distributed to capital owners. Firms are modeled in subsection 2.3.

Private banks On the asset side, private banks make loans to private firms and purchase government bonds. On the side of liabilities, they receive deposits from savers and loans from the national central bank. To model the profit-maximizing behavior of private banks, and also account for the possibility that borrowing and lending takes place in equilibrium, we adopt the framework introduced by Curdia and Woodford (2010, 2011) and in turn used by Corsetti et al. (2013) and many others.[7] Within this framework, the difference between deposit and lending interest rate emerges as a result of heterogeneity in patience between savers (workers and public employees) and borrowers (firms or, equivalently their owners, capital owners) as well as of costly financial intermediation. Any profits generated by private banks are distributed to capital owners. Banks are modeled in subsection 2.4.

State firms State firms use public employees, goods purchased from the private sector and public capital (the latter is augmented by public investment spending) to produce a public good that provides utility-enhancing services to households and productivity-enhancing services to firms, where the associated spending inputs as shares of GDP, as well as the fraction of public employees in population, will be set as in the data. State firms are in subsection 2.5.

National central bank (NCB) in the Eurosystem (ES) On the side of assets, the NCB makes loans to private banks and can also hold government bonds. On the liabilities side, the monetary base consists of banknotes and cross-border *TARGET2* liabilities (these are the two largest liability items in the Greek data; by contrast, reserves held by private banks at the Greek NCB are small in magnitude and so are assumed away). In

[7] The model of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) is another popular model in this literature. We do not believe the particular model of the banking sector is important to our results. We use the Curdia-Woodford model for its relative simplicity. Walsh (2017, chapter 11) reviews this literature.

other words, the NCB's spending is financed by printing new banknotes held by private agents and by issuing *TARGET2* liabilities to other NCB's according to the rules of the ES. Any portfolio profits generated by the NCB are transferred to its government in the form of a lump-sum dividend. The NCB is modeled in subsection 2.6.3.

Treasury or the government On the revenue side, the Treasury, or the government, taxes income and consumption, receives a dividend from its NCB and/or from the ECB and issues sovereign bonds. The latter can be purchased by domestic investors (domestic private banks and the national central bank) and by foreign investors (where foreign investors can be both private and public like EU institutions and the ECB). On the expenditure side, the Treasury spends on wages of public employees, government investment, government purchases of goods from the private sector, as well as transfer payments to households. This is in subsection 2.6.2.

Macroeconomic policy regime We assume that, during the years of the Greek sovereign debt crisis, monetary policy was shaped by the public and banking financing needs of the country. Specifically, we assume that, during these years, the ECB followed an accommodative policy towards Greece, in the sense that quantitative monetary policies, and in particular the issuance of *TARGET2* liabilities to the ES, were adjusted so as to ensure that Greece's consolidated government budget constraint was satisfied in each period, while the tax-spending-public debt mix (including the official fiscal bailouts) is set as in the data. This is analysed in subsection 2.6.5.

Stationarity in a small open economy As is known, we need an "imperfection" to get a stationary solution in a small-open economy model. Popular devices include a debt-elastic interest rate when agents borrow from abroad, or a transaction cost again when agents borrow from abroad, or an endogenous time preference rate (see e.g. Schmitt-Grohe and Uribe (2003)). Here, to bring the dynamics of the model closer to the data, we will assume both a debt-elastic country interest rate and transaction costs, although one is enough to guarantee stationarity. The country debt-elastic interest rate is in subsection 2.8, while transaction costs associated with borrowing from private foreign markets are in subsections 2.2.1 and 2.6.2.

Institutions As said above, in most situations, poor institutions show up in ill-defined property rights and the most common way of modeling the latter has been to assume that private and/or communal properties become "common pools".[8] Then, access to a common pool distorts individual incentives to work or save and this leads to resource misallocation and poor macroeconomic performance. Here, we will assume that, because of weak property rights, producers can appropriate only a fraction of their

[8] See e.g. Persson and Tabellini (2000, chapter 14), Drazen (2000, chapters 8 and 10), Hillman (2009, chapter 2), Besley and Ghatak (2010), Grossman (2001) and Acemoglu and Robinson (2019) for common-pool problems, weak property rights and extraction.

output, while the rest can be taken away by rent seekers, where the latter are assumed to be all types of households who compete with each other for a fraction of the contestable prize in a Tullock-type redistributive contest. Our measure of the degree of property rights will be set as in the data, while the rent-seeking technology is specified in subsections 2.2 and 2.3.2.

Modelling details will be provided as we present each building block of the above described model.

Two early remarks Before we proceed, we wish to make two early remarks about the model. First, by assuming market-clearing in the labor market(s), any fall in output is obviously reflected in a fall in hours of work rather than in unemployed people. This is for simplicity. We have experimented with an extended version of our model that allows for both less hours of work and less employed people whenever output happens to fall. In particular, we have implemented this by replacing the supply of labor function with a wage rigidity rule as in e.g. Blanchard and Gali (2007), and where any decrease in the demand for labor on the part of firms is divided between a decrease in work hours and a decrease in the number of working people as in Ball and Romer (1990). Since the main results are not affected by this extension, we present the version of the model without unemployed people. Second, we will not model explicitly the fear of being forced out of the eurozone (what has been known as the fear of Grexit). Nevertheless, most indices of institutional quality are based on both observable data and perceptions; the index for the enforcement of property rights used in our paper is not an exception. In other words, this index reflects both hard data and perceptions/sentiments, and the latter can incorporate the fear of Grexit affecting (among other things) private sector's expectations about future factor returns and economic policies. Besides, in the data, measures of core institutional fundamentals (like the rule of law, etc) are strongly correlated with measures of country risk (like the International Country Risk Guide, ICRG).[9] In any case, we will return to this point in the last concluding section.

2.2 Households

There are three distinct types of households, called capital owners, workers and public employees. Capital owners are indexed by the subscript $k = 1, 2, ..., N^k$, workers by the subscript $w = 1, 2, ...N^w$, and public employees by the subscript $b = 1, 2, ..., N^b$. That is, the total population is $N = N^k + N^w + N^b$. Equivalently, in terms of population ratios, we define $n^k \equiv \frac{N^k}{N}$, $n^w \equiv \frac{N^w}{N}$ and $n^b \equiv \frac{N^b}{N} = 1 - n^k - n^w$. For simplicity, total population and its decomposition to the three groups is exogenous and kept constant over time; we also assume away occupational mobility from one group to another.

[9] See e.g. Christou et al. (2020) for a number of Eurozone countries including Greece.

2.2.1 Households as capital owners

There are $k = 1, 2, ..., N^k$ identical capital owners. These households own the firms and banks and receive their profits. They also have the opportunity to participate in the international asset market. Besides, like all other types of households, they receive income from work, hold currency and are engaged in rent-seeking activities.

Each k maximizes discounted lifetime utility:

$$\sum_{t=0}^{\infty}(\beta_k)^t u\left(c_{k,t}, u_{k,t} h_{k,t}; \overline{y}_t^g\right) \tag{1}$$

where $c_{k,t}$, $u_{k,t}$ and $h_{k,t}$ denote respectively k's consumption, leisure time and end-of-period currency (in real terms),[10] $\overline{y}_t^g$ denotes the per capita quantity of public goods/services provided and produced by the government, and $0 < \beta_k < 1$ is capital owners' time discount factor.

For our numerical solutions, we will use the utility function:

$$u\left(c_{k,t}, u_{k,t}, h_{k,t}; \overline{y}_t^g\right) = \mu_1 \log c_{k,t} + \mu_2 \log u_{k,t} + \mu_3 \log h_{k,t} + \mu_4 \log \overline{y}_t^g$$

where $0 < \mu_1,\ \mu_2,\ \mu_3,\ \mu_4 < 1$ are preference parameters with $\mu_1 + \mu_2 + \mu_3 + \mu_4 = 1$.

Since there are two goods, home and foreign, we define the consumption index:

$$c_{k,t} = \frac{(c_{k,t}^h)^{\nu}(c_{k,t}^f)^{1-\nu}}{\nu^{\nu}(1-\nu)^{1-\nu}} \tag{2}$$

where $c_{k,t}^h$ and $c_{k,t}^f$ denote k's domestic and foreign consumption respectively and $0 < \nu < 1$ measures the weight given to the domestic good relative to the foreign good.

The time constraint of each k in each period is:

$$l_{k,t} + s_{k,t} + u_{k,t} = 1 \tag{3a}$$

where $l_{k,t}$ and $s_{k,t}$ are respectively k's effort time allocated to productive work and anti-social or rent seeking activities.

The within-period budget constraint of each k written in real terms is:

$$(1+\tau_t^c)\left(\frac{p_t^h}{p_t}c_{k,t}^h + \frac{p_t^f}{p_t}c_{k,t}^f\right) + (1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}f_{k,t-1} +$$

$$+ q_t R_{k,t} + \frac{p_t^h}{p_t}\psi^p(.) + h_{k,t} \equiv$$

[10] To give currency a role, we use a money-in-the-utility-function model. Alternatively, we could use a cash-in-advance model. This is not important to our results.

$$\equiv (1-\tau_t^y)w_t^k l_{k,t} + (q_t + \pi_{k,t}^i)R_{k,t-1} + \pi_{k,t}^p$$
$$+\frac{e_t p_t^*}{p_t} f_{k,t} + \frac{p_{t-1}}{p_t} h_{k,t-1} + \overline{g}_t^{tr} +$$
$$+\left(\frac{\Gamma^k(s_{k,t})^\gamma}{N^k\Gamma^k(s_{k,t})^\gamma + N^w\Gamma^w(s_{w,t})^\gamma + N^b\Gamma^b(s_{b,t})^\gamma}\right)(1-PR_t)Y_t \tag{3b}$$

where p_t^h is the price of the domestic good, p_t^f is the price of the foreign good expressed in domestic currency, p_t is the country's CPI specified below, p_t^* is the CPI abroad, e_t is the nominal exchange rate (an increase means a depreciation), $f_{k,t}$ is the real value of one-period foreign debt denominated in foreign prices and acquired by each k at t on which k pays the country-specific nominal interest rate i_{t+1}^* at $t+1$ (if k is a lender, $f_{k,t} < 0$ and i_{t+1}^* denotes a return),[11] $R_{k,t}$ denotes the number of firms' shares purchased by each k at time t at a price q_t, w_t^k is the real wage rate paid to capital owners, $\pi_{k,t}^i$ stands for the share's dividend paid to each k by private firms net of taxes, $\pi_{k,t}^p$ is the profit generated by private banks and paid to each k net of taxes, $h_{k,t}$ is the real value of currency carried over from t to $t+1$, $\psi^p(.)$ is a transaction cost function associated with the agent's participation in the foreign capital market (defined below), $\overline{g}^{tr}$ is a uniform transfer from the government and $0 \leq \tau_t^c$, $\tau_t^y < 1$ are the tax rates on final consumption goods and income.

The last term on the RHS of (3b) is the amount extracted by each k from the common pool. Given weak property rights, we assume that total real output, defined as Y_t,[12] is a common pool or a contestable prize, so that only a fraction of it, PR_tY_t, remains in the hands of its producers because the rest, $(1-PR_t)Y_t$, is taken away by rent seekers, where the rents extracted by each person depend on the anti-social activities employed by him/her relative to total anti-social activities.[13] That is, $0 < PR_t \leq 1$ is the degree of protection of property rights and the term $\left(\frac{\Gamma^k(s_{k,t})^\gamma}{N^k\Gamma^k(s_{k,t})^\gamma+N^w\Gamma^w(s_{w,t})^\gamma+N^b\Gamma^b(s_{b,t})^\gamma}\right)$ is the fraction of the common pool extracted by each k in a Tullock (1980) type rent-seeking competition. Regarding the rent-seeking technology, as in e.g.

[11] This is denominated in foreign currency. That is, if $F_{k,t}$ is the nominal value for each agent k, the real value is $f_{k,t} \equiv \frac{F_{k,t}}{p_t^*}$.

[12] As we shall see below, $Y_t \equiv N^i \frac{p_t^h}{p_t} y_{i,t}^h$, where N^i is the number of private firms and $y_{i,t}^h$ is the product of each of those firms.

[13] Ill-defined property rights obviously hurt those who are productive and so reduce their incentives to produce and invest (see below the firm's problem), but there are social losses on the side of predators as well, since the pursuit of a share of a contestable prize, where contestability is made possible by weak property rights or ill-meant publicness, distorts their own incentives and talents (see e.g. Murphy et al (1991), Hillman (2009, chapter 2), Besley and Ghatak (2010), Esteban and Ray (2011) and Acemoglu and Robinson (2019)). This is the case in our model with Tullock-type rent seeking competition. Quantitative DSGE models with similar extraction technology include Angelopoulos et al. (2009) and Christou et al. (2020).

Dixit (2004, chapter 5) and Hillman (2009, chapter 2), the power coeffcient, γ, is between 0 and 1 and measures how quickly diminishing returns arise in anti-social activities, while the parameter Γ^k measures the efficacy of k's aggresion. Both are measures of the technology of fighting. If Γ^k increases and/or γ decreases, agent k has a stronger incentive to devote effort time to rent seeking. Note that this specification, specifically, the different values of Γ^k, Γ^w and Γ^b, allows us to have asymmetries in equilibrium; namely, different types of rent seekers can choose different allocations and receive different wages even if they attack the same pie and share the same preferences.

Regarding the per agent cost associated with participation in the foreign financial market, it is assumed to take the form:

$$\psi^p(.) \equiv \frac{1}{N_t^k}\frac{\psi^p}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(N_t^k f_{k,t} + F_t^g\right)}{\frac{p_t^h}{p_t}Y_t} - \overline{f}\right]^2 Y_t \tag{4}$$

where $\psi^p \geq 0$ is a transaction cost parameter associated with participation in foreign capital markets, F_t^g denotes total public foreign debt (i.e. public debt issued by the domestic government and held by foreign private investors) denominated in foreign currency,[14] $N_t^k f_{k,t}$ denotes total private foreign debt denominated in foreign currency, Y_t is total real output and the parameter $\overline{f}$ is a threshold value of the country's foreign debt as share of GDP above which such costs arise. In other words, the cost is increasing in the country's total real foreign debt to total real GDP.

Each k acts competitively choosing $\{c_{k,t}^h,\ c_{k,t}^f,\ c_{k,t},\ l_{k,t},\ s_{k,t},\ R_{k,t},\ f_{k,t},\ h_{k,t}\}_{t=0}^{\infty}$ subject to the above. The first-order conditions are in Appendix A.1 of the supplementary file.

2.2.2 Households as workers

There is a pool of $w = 1, 2, ..., N^w$ identical households-workers. They are employed by private firms (see below). Like all other households, workers consume, work, hold currency and participate in rent-seeking activities. Workers can also save in the form of bank deposits.[15]

Each worker w maximizes:

$$\sum_{t=0}^{\infty}\beta^t u\left(c_{w,t}, u_{w,t}, h_{w,t}; \overline{y}_t^g\right) \tag{5}$$

where variables are defined as above in the capital owners' problem if we replace the subscript k with the subscript w and $0 < \beta < 1$ is workers' time

[14] For more details, see the government budget constraint below.

[15] The assumption that workers and public employees do not participate in all asset markets is without loss of generality. We could assume that all households face transaction costs that make costly their participation in asset markets but workers and public employees face higher costs.

discount factor. We will assume $0 < \beta_k < \beta < 1$, which will induce savers (here, workers and public employees) to have bank deposits and borrowers (here, firms) to take on debt in equilibrium.[16]

As above, we use the utility function:

$$u\left(c_{w,t}, u_{w,t}, h_{w,t}; \overline{y}_t^g\right) = \mu_1 \log c_{w,t} + \mu_2 \log u_{w,t} + \mu_3 \log h_{w,t} + \mu_4 \log \overline{y}_t^g$$

and the consumption index:

$$c_{w,t} = \frac{(c_{w,t}^h)^\nu (c_{w,t}^f)^{1-\nu}}{\nu^\nu (1-\nu)^{1-\nu}} \tag{6}$$

Also, as above, the maximization is subject to the time constraint:

$$l_{w,t} + s_{w,t} + u_{w,t} = 1 \tag{7a}$$

and the budget constraint:

$$(1+\tau_t^c)\left(\frac{p_t^h}{p_t}c_{w,t}^h + \frac{p_t^f}{p_t}c_{w,t}^f\right) + j_{w,t} + h_{w,t} \equiv$$

$$\equiv (1-\tau_t^y) w_t^w l_{w,t} + (1+i_t^d)\frac{p_{t-1}}{p_t} j_{w,t-1} + \frac{p_{t-1}}{p_t} h_{w,t-1} + \overline{g}_t^{tr} +$$

$$+ \left(\frac{\Gamma^w (s_{w,t})^\gamma}{N^k \Gamma^k (s_{k,t})^\gamma + N^w \Gamma^w (s_{w,t})^\gamma + N^b \Gamma^b (s_{b,t})^\gamma}\right)(1 - PR_t) Y_t \tag{7b}$$

where w_t^w is the real wage rate of workers and $j_{w,t}$ is the real value of each w's bank deposits chosen at t and paying a nominal interest rate i_{t+1}^d at $t+1$. Notice that workers are assumed to have access to the same contestable prize as all other agents. They also receive the same transfer paid by the government to all other households.

Each w acts competitively choosing $\{c_{w,t}^h, c_{w,t}^f, c_{w,t}, l_{w,t}, s_{w,t}, j_{w,t}, h_{w,t}\}_{t=0}^\infty$ subject to the above. The first-order conditions are in Appendix A.2 of the supplementary file.

2.2.3 Households as public employees

There are $b = 1, 2, ..., N^b$ identical public employees. They are employed by state firms (see below). Like all other households, public employees consume, work, hold currency and are engaged in rent-seeking activities.

[16] See also e.g. Benigno et al. (2014), Korinek and Simsek (2016) and Philippopoulos et al. (2017b) for permanent differences in discount factors between savers and borrowers. Curdia and Woodford (2010, 2011) also assume differences in the degree of impatience among savers and borrowers although this difference does not remain fixed over time (this is not important to our results). Also, in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011), bankers face a probability of exit, which effectively reduces their time discount factor as in the perpetual youth model of Blanchard (1985).

Also, like workers, they can save in the form of bank deposits. Variables will be defined as above in the workers' problem if we replace the subscript w with the subscript b.

Each b maximizes:

$$\sum_{t=0}^{\infty}\beta^t u\left(c_{b,t}, u_{b,t}, h_{b,t}; \overline{y}_t^g\right) \tag{8}$$

As above, the ulility function and the consumption index are:

$$u\left(c_{b,t}, 1-l_{b,t}, h_{b,t}; \overline{y}_t^g\right) = \mu_1 \log c_{b,t} + \mu_2 \log u_{b,t} + \mu_3 \log h_{b,t} + \mu_4 \log \overline{y}_t^g$$

$$c_{b,t} = \frac{(c_{b,t}^h)^{\nu}(c_{b,t}^f)^{1-\nu}}{\nu^{\nu}(1-\nu)^{1-\nu}} \tag{9}$$

Also, as above, the maximization is subject to the time constraint:

$$l_{b,t} + s_{b,t} + u_{b,t} = 1 \tag{10a}$$

and the budget constraint:

$$(1+\tau_t^c)\left(\frac{p_t^h}{p_t}c_{b,t}^h + \frac{p_t^f}{p_t}c_{b,t}^f\right) + j_{b,t} + h_{b,t} \equiv$$

$$\equiv (1-\tau_t^y)w_t^g l_{b,t} + (1+i_t^d)\frac{p_{t-1}}{p_t}j_{b,t-1} + \frac{p_{t-1}}{p_t}h_{b,t-1} + \overline{g}_t^{tr} +$$

$$+\left(\frac{\Gamma^b(s_{b,t})^{\gamma}}{N^k\Gamma^k(s_{k,t})^{\gamma} + N^w\Gamma^w(s_{w,t})^{\gamma} + N^b\Gamma^b(s_{b,t})^{\gamma}}\right)(1-PR_t)Y_t \tag{10b}$$

where w_t^g is the real wage in the public sector while the rest of the variables are defined as in the worker's problem.

Each b acts competitively choosing $\{c_{b,t}^h,\ c_{b,t}^f,\ c_{b,t},\ l_{b,t},\ s_{b,t},\ j_{b,t},\ h_{b,t}\}_{t=0}^{\infty}$ subject to the above.[17] The first-order conditions are in Appendix A.3 of the supplementary file.

2.3 Private firms and production of private goods

Private firms are owned by capital owners. Following most of the related literature, there are three types of goods produced by three associated types of firms. There is a single domestic final good produced by competitive final good firms. There are also differentiated intermediate goods used as inputs for the production of the final good. Each differentiated intermediate good is produced by an intermediate goods firm that acts as a monopolist in its own

[17] The choice of $l_{b,t}$ can be thought as a choice of work effort. Allowing for a fixed shift, or hours of work, in the public sector would not change our results to the extent that public employees can still choose the effort they make while at work.

product market à la Dixit-Stiglitz facing Rotemberg-type nominal fixities. Finally, competitive capital good firms produce capital used as an input in the production of intermediate goods. As in most of the related literature, the essential role is played by intermediate goods firms.

2.3.1 Final good firms

There are N^h final good firms indexed by subscript $h = 1, 2, ..., N^h$. For notational simplicity, we will set $N^h = N^k$, that is, the number of final good firms equals the number of their owners. Each final good firm produces an amount $y^h_{h,t}$ by using intermediate goods according to the standard Dixit-Stiglitz technology:

$$y^h_{h,t} = \left[\sum_{i=1}^{N^i} \frac{1}{N^i} (y^h_{i,t})^{\theta} \right]^{\frac{1}{\theta}} \tag{11}$$

where $y^h_{i,t}$ denotes the quantity of intermediate good of variety $i = 1, 2, ..., N^i_t$ used by each final good firm h and $0 \leq \theta \leq 1$ is a parameter measuring the degree of substitutability (when $\theta = 1$, intermediate goods are perfect substitutes in the production of the final good and the intermediate goods sector is perfectly competitive).

Each final-good producer chooses $y^h_{i,t}$ to maximize real profits:

$$y^h_{h,t} - \sum_{i=1}^{N^i} \frac{1}{N^i} \frac{p^h_{i,t}}{p^h_t} y^h_{i,t} \tag{12}$$

where p^h_t is the price of the final good and $p^h_{i,t}$ is the price of intermediate good i.

The firm maximizes its profit acting competitively subject to the above. The familiar first-order condition for inputs used is in Appendix A.4 of the supplementary file.

2.3.2 Intermediate goods firms

There are N^i intermediate goods firms indexed by the subscript $i = 1, 2, ..., N^i$. Since they are owned and managed by capital owners, we again set $N^i = N^k$ for notational simplicity. These firms make investment and other factor decisions facing capital and Rotemberg-type price adjustment costs. New investment is financed by retained earnings, by issuing shares and by obtaining loans from private banks.[18]

[18] We will work similarly to e.g. Miao (2014, chapter 14) and Uribe and Schmitt-Grohe (2017, chapter 4). Our modelling also follows e.g. Brock and Turnovsky (1981), Altug and Labadie (1994, chapter 4) and Turnovsky (1995, chapter 11), although these papers solve a more general corporate finance problem (see below).

The gross profit of each intermediate goods firm i, denoted as $\pi_{i,t}^{gross}$, is defined as sales minus the wage bill minus the cost of imported goods minus adjustment costs associated with changes in capital and prices:

$$\pi_{i,t}^{gross} \equiv PR_t \frac{p_{i,t}^h}{p_t} y_{i,t}^h - w_t^w l_{i,t}^w - w_t^k l_{i,t}^k - \frac{p_t^f}{p_t} m_{i,t}^f -$$

$$-\frac{p_t^h}{p_t} \frac{\xi^k}{2} \left(\frac{k_{i,t}}{k_{i,t-1}} - 1 \right)^2 k_{i,t-1} - \frac{p_t^h}{p_t} \frac{\xi^p}{2} \left(\frac{p_{i,t}^h}{p_{i,t-1}^h} - 1 \right)^2 \overline{y}_{i,t}^h \tag{13a}$$

where $l_{i,t}^w$ is labor services provided by workers and used by firm i, $l_{i,t}^k$ is labor services provided by capital owners and used by i, $m_{i,t}^f$ is imported goods used by each i, $k_{i,t}$ is capital goods purchased from capital good producers by each i in the current period and used in the next period (as we shall see below, the relative price of capital is 1), ξ^k is a parameter measuring standard capital adjustment costs and ξ^p is a parameter measuring Rotemberg-type price adjustment costs.[19] Finally, as said above, firms can appropriate only a fraction, $0 < PR_t \leq 1$, of their output because of poor institutional quality.

This gross profit is held as retained earnings and is also used for the payment of corporate taxes to the government, dividends to shareholders and interest payments for loans received from private banks:

$$\pi_{i,t}^{gross} \equiv RE_{i,t} + \tau_t^\pi \left(PR_t \frac{p_{i,t}^h}{p_t} y_{i,t}^h - w_t^w l_{i,t}^w - w_t^k l_{i,t}^k - \frac{p_t^f}{p_t} m_{i,t}^f \right) +$$

$$+\pi_{i,t} R_{i,t-1} + i_t^l \frac{p_{t-1}}{p_t} L_{i,t-1} \tag{13b}$$

where $RE_{i,t}$ is retained earnings, $0 \leq \tau_t^\pi < 1$ a tax rate, $\pi_{i,t}$ is the dividend paid to shareholders for each share, $R_{i,t-1}$ is the beginning-of-period number of shares and $L_{i,t-1}$ denotes the inherited bank loan on which the firm pays a nominal interest rate, i_t^l.

Purchases of new capital, i.e. investment, are financed by retained earnings, issuance of new shares and a new loan from private banks:

$$\frac{p_t^h}{p_t} \left[k_{i,t} - (1-\delta) k_{i,t-1} \right] \equiv RE_{i,t} + (R_{i,t} - R_{i,t-1}) q_t + (L_{i,t} - \frac{p_{t-1}}{p_t} L_{i,t-1}) \tag{13c}$$

where q_t is the relative price of shares (see also the capital owners' budget constraint above).

[19] Notice that Rotemberg-type costs associated with price changes are assumed to be proportional to average output, $\overline{y}_{i,t}^h$, which is taken as given by each i. This proportionality is not important but helps the smooth dynamics of the model.

Combining the above constraints, we get:

$$(1-\tau_t^{\pi})\left[PR_t\frac{p_{i,t}^h}{p_t}y_{i,t}^h - w_t^w l_{i,t}^w - w_t^k l_{i,t}^k - \frac{p_t^f}{p_t}m_{i,t}^f\right]-$$

$$-\frac{p_t^h}{p_t}\left[k_{i,t}-(1-\delta)k_{i,t-1}\right]-$$

$$-\frac{p_t^h}{p_t}\frac{\xi^k}{2}\left(\frac{k_{i,t}}{k_{i,t-1}}-1\right)^2 k_{k,t-1} - \frac{p_t^h}{p_t}\frac{\xi^p}{2}\left(\frac{p_{i,t}^h}{p_{i,t-1}^h}-1\right)^2 \overline{y}_{i,t}^h \equiv$$

$$\equiv \pi_{i,t}R_{i,t-1} - (R_{i,t}-R_{i,t-1})q_t - \left(L_{i,t}-(1+i_t^l)\frac{p_{t-1}}{p_t}L_{i,t-1}\right) \tag{13d}$$

where the left-hand side is the net cash flow of the firm.

Setting the number of shares at one, $R_{i,t} \equiv 1$ at any t, the firm's dividend or net profit, $\pi_{i,t}$, simplifies to:[20]

$$\pi_{i,t} \equiv (1-\tau_t^{\pi})\left[PR_t\frac{p_{i,t}^h}{p_t}y_{i,t}^h - w_t^w l_{i,t}^w - w_t^k l_{i,t}^k - \frac{p_t^f}{p_t}m_{i,t}^f\right]-$$

$$-\frac{p_t^h}{p_t}\left[k_{i,t}-(1-\delta)k_{i,t-1}\right] - \frac{p_t^h}{p_t}\frac{\xi^k}{2}\left(\frac{k_{i,t}}{k_{i,t-1}}-1\right)^2 k_{k,t-1}-$$

$$-\frac{p_t^h}{p_t}\frac{\xi^p}{2}\left(\frac{p_{i,t}^h}{p_{i,t-1}^h}-1\right)^2 \overline{y}_{i,t}^h+$$

$$+\left(L_{i,t}-(1+i_t^l)\frac{p_{t-1}}{p_t}L_{i,t-1}\right) \tag{14}$$

For the firm's production function, we adopt the form:

$$y_{i,t}^h = A^p\left(\frac{N^g y_{g,t}^g}{N^i}\right)^{\sigma}\left[\left(\chi^p(k_{i,t-1})^{op}+(1-\chi^p)(m_{i,t}^f)^{op}\right)^{\frac{\alpha}{op}}\left(A^w l_{i,t}^w + A^k l_{i,t}^k\right)^{1-\alpha}\right]^{1-\sigma} \tag{15}$$

where the parameter $0 \leq \chi^p \leq 1$ measures the intensity of capital, $k_{i,t-1}$, relative to goods imported from abroad, $m_{i,t}^f$, the parameter $op \geqslant 0$ measures the degree of substitutability between capital and imported goods, the coefficient $1-a$ gives the share of labor inputs used by the firm, the parameters A^w and A^k measure the relative productivity of workers and capital owners respectively, $A^p > 0$ is TFP in the private sector and $0 \leq \sigma \leq 1$ is the contribution of public goods/services per firm to private production.

[20] This is as in e.g. Miao (2014, chapter 14) and Uribe and Schmitt-Grohe (2017, chapter 4). Imposing this market-clearing condition ex ante makes the problem of the firm simpler. Otherwise, see e.g. Brock and Turnovsky (1981), Altug and Labadie (1994, chapter 4) and Turnovsky (1995, chapter 11).

Firms are assumed to be subject to a borrowing constraint.[21] Following most of the related literature (see e.g. Garin (2015), Guntner (2015), etc), we assume that firms can borrow up to a fraction of their capital:

$$L_{i,t} \leq \rho^{l} \frac{p_{t}^{h}}{p_{t}} k_{i,t-1} \tag{16}$$

where the parameter $\rho^{l} \geq 0$ measures the tightness of borrowing conditions.

Therefore, each firm i maximizes the discounted sum of dividends distributed to its owners:

$$\sum_{t=0}^{\infty} (\beta_{i,t})^{t} \pi_{i,t} \tag{17}$$

where, since firms are owned by capital owners, we will ex post postulate that the firm's discount factor, $\beta_{i,t}$, equals the capitall owners' marginal rate of substitution between consumption at t and $t+1$, $\beta_{i,t} \equiv \frac{\beta_{k}(1+\tau_{t}^{c})c_{k,t}}{(1+\tau_{t+1}^{c})c_{k,t+1}}$.[22]

The firm chooses $\{l_{i,t}^{w},\ l_{i,t}^{k},\ m_{i,t}^{f},\ k_{i,t},\ L_{i,t}\}_{t=0}^{\infty}$ to maximize its stream of dividends or net profits, as defined in (14) and (17), subject to the production function in (15), the borrowing constraint in (16) and the inverse demand function for its product coming from the final good firm's problem. Details and the firm's first-order conditions are in Appendix A.5 of the supplementary file.

2.3.3 Capital good firms

There are N^{c} capital good firms indexed by the subscript $c = 1, 2, ..., N^{c}$. Since they are owned by capital owners, we again set $N^{c} = N^{k}$ for notational simplicity. Working similarly to e.g. Guntner (2015), Uribe and Schmitt-Grohe (2017, pp. 79 and 110), and many others, we assume that capital good producers aquire the depreciated capital stock, choose investment activity and sell the latter to intermediate goods firms. Here, this problem is modeled in the simplest possible way by assuming away adjustment costs, so that, in each period, each firm c maximizes its profit given by:

$$\pi_{c,t} \equiv Q_{t} x_{c,t} - x_{c,t} \tag{18}$$

where $x_{c,t}$ is the amount of investment produced and Q_{t} is the relative price of capital also known as Tobin's q. Here, without capital adjustment costs, the first-order condition is simply $Q_{t} = 1$ as assumed above. Also, the profit is zero in equilibrium.

[21] We could assume different types of constraints as in e.g. Uribe and Schmitt-Grohe (2017) and Sims and Wu (2020). We do not believe this is important to our results.

[22] See also e.g. Altug and Labadie (1994, pp. 165-6), Gertler and Karadi (2011) and Uribe and Schmitt-Grohe (2017, pp. 110-111).

2.4 Private banks

There are N^p private banks indexed by the subscript $p = 1, 2, ..., N^p$. Since they are owned and managed by capital owners, we again set $N^p = N^k$ for notational simplicity. In addition to their standard role, which is the provision of intermediation between lenders and borrowers by converting bank deposits into loans to firms, we also allow private banks to receive loans from the NCB and to purchase government bonds. Therefore, on the side of liabilities, private banks receive deposits from households and take loans from the NCB, while, on the asset side, they make loans to private firms and purchase government bonds. As said above, we do not include reserves held by private banks at the NCB; this is simply because they are small in the Greek data (for financial statements of the Bank of Greece, see subsection 3.2 below). Any profits made by banks are distributed to their owners, namely the entrepreneurs.

The budget constraint of each p that connects changes in its assets and liabilities is (written in real and per capita terms):

$$L_{p,t} + b_{p,t} + \pi_{p,t} + (1 + i_t^d)\frac{p_{t-1}}{p_t} j_{p,t-1} +$$

$$+\frac{p_t^h}{p_t}\Xi(L_{p,t}, z_{p,t}, b_{p,t}) + (1 + i_t^z)\frac{p_{t-1}}{p_t} z_{p,t-1} \equiv$$

$$\equiv (1 + i_t^l)\frac{p_{t-1}}{p_t} L_{p,t-1} + (1 + i_t^*)\frac{p_{t-1}}{p_t} b_{p,t-1} + j_{p,t} + z_{p,t} \tag{19}$$

where $L_{p,t}$ is loans given to firms on which banks receive the nominal interest rate i_{t+1}^l one period later, $b_{p,t}$ is one-period government bonds purchased by banks at t on which banks receive the country-specific nominal interest rate i_{t+1}^* one period later, $\pi_{p,t}$ is bank p's profits distributed to bank owners in a lump-sum fashion, $j_{p,t}$ is bank deposits on which banks pay the nominal interest rate i_{t+1}^d one period later, $z_{p,t}$ is loans from the NCB to the private bank on which private banks pay the nominal policy interest rate i_{t+1}^z one period later and $\Xi(L_{p,t}, z_{p,t}, b_{p,t})$ is real operational costs faced by banks that are assumed to be increasing in the volume of loans given to firms, increasing in the volume of loans taken from the NCB and decreasing in holdings of government bonds (the latter captures the idea that government bonds are used as a collateral for taking loans from the NCB). In what folows, we will use the functional form $\Xi(L_{p,t}, b_{p,t}) = \frac{\xi^l}{2}(L_{p,t})^2 + \frac{\xi^z}{2}(z_{p,t})^2 + \frac{\xi^b}{2}(b_{p,t})^{-2}$ which can give well-defined demand and supply functions.[23]

Loans from the NCB to private banks are assumed to be subject to a borrowing constraint. Similarly to the firm's problem above, we assume that each private bank can borrow up to a fraction of its assets:

$$z_{p,t} \leq \rho^z(L_{p,t} + b_{p,t}) \tag{20}$$

[23] In Curdia and Woodford (2010, 2011), the banks intermediate between borrowers and lenders and the associated intermediation cost falls with reserves held at the central bank.

where the parameter $\rho^z \geq 0$ measures teh tightness of borrowing conditions.

The bank's profit maximization problem subject to the above is solved as in Curdia and Woodford (2010, 2011) and Corsetti et al (2013). Modeling details and first-order conditions for the supply of loans to firms, $L_{p,t}$, and the demand for credit from the NCB, $z_{p,t}$, in each period, are in Appendix A.6 of the supplementary file. Notice that we can also derive optimally the demand for government bonds, $b_{p,t}$. However, instead of choosing $b_{p,t}$ optimally, we prefer to simply set it (namely, the fraction of Greek public debt purchased by private domestic banks) exogenously as in the data. This helps us to bring the model closer to the data and can be justified by the fact that, in Greece, there is a nexus of public-finance policy and private banks (see e.g. Brunnermeier and Reis (2019) for this nexus in EZ periphery countries).

2.5 State firms and production of public goods/services

We now model the way in which state enterprises produce the publicly provided good/service. There are N^g state firms indexed by the subscript $g = 1, 2, ..., N^g$ producing a single public good/service. For notational simplicity, we will set $N^g = N^b$, that is, the number of state firms equals the number of public employees.

The cost of each state firm g for producing the public good is in real terms:

$$w_t^g l_{g,t} + \frac{p_t^h}{p_t}(g_{g,t}^g + g_{g,t}^i) + \frac{p_t^f}{p_t} m_{g,t}^g \tag{21}$$

where $l_{g,t}$ is labor services used by each state firm g, $g_{g,t}^g$ is goods purchased from the private sector by each g, $g_{g,t}^i$ is investment made by each g, and $m_{g,t}^g$ is imported goods used by each g.

The production function of each state firm g is assumed to be similar to that in the private sector:

$$y_{g,t}^g = A^g \left(\chi^g (k_{g,t-1}^g)^{og} + (1-\chi^g)(m_{g,t}^g)^{og}\right)^{\frac{\theta_1}{og}} (l_{g,t})^{\theta_2} \left(g_{g,t}^g\right)^{1-\theta_1-\theta_2} \tag{22}$$

where $0 \leq \chi^g \leq 1$ measures the intensity of public capital, $k_{g,t-1}^g$, relative to goods imported from abroad, $m_{g,t}^g$, the parameter $og \geqslant 0$ measures the degree of substitutability between public capital and imported goods, the coefficients $0 < \theta_1$, θ_2, $1 - \theta_1 - \theta_2 < 1$ measure the shares of the associated factors in production and $A^g > 0$ is TFP in the public sector.

The stock of each state firm's capital evolves over time as:

$$k_{g,t}^g = (1-\delta^g) k_{g,t-1}^g + g_{g,t}^i \tag{23}$$

where $0 < \delta^g < 1$ is the depreciation rate of public capital.

To specify the level of output produced by each state firm, $y^g_{g,t}$, and hence the total amount of public goods/services provided to the society, we obviously have to specify the amounts of inputs, $l_{g,t}$, $g^g_{g,t}$, $m^g_{g,t}$ and $k^g_{g,t}$ (or equivalently $g^i_{g,t}$). Except from work hours or effort which is determined by public employees (see their problem above), we will consider the case in which the values of these inputs are as implied by the actual data, meaning that the total number of public employees as a share of population, as well as the associated government expenditures (on public investment, public wages, goods purchased from the private sector and imported goods) as shares of GDP, are set as in the data. Specifically, we define $g^i_{g,t} = \frac{s^i_t n^k y^h_{i,t}}{n^b}$, $g^g_{g,t} = \frac{s^g_t n^k y^h_{i,t}}{n^b}$, $m^g_{g,t} = \frac{p^h_t}{p^f_t} \frac{s^m_t n^k y^h_{i,t}}{n^b}$ and $w^g_t = \frac{s^w_t \frac{p^h_t}{p_t} n^k y^h_{i,t}}{n^b l_{b,t}}$, where $n^b \equiv \frac{N^b}{N}$ is the fraction of public employees in population and s^i_t, s^g_t, s^m_t and s^w_t are respectively the GDP shares of government expenditures on investment, goods purchased from the private sector, imported goods and public wages; these values will be set according to the data (see subsection 3.2 below).

2.6 Fiscal and monetary policy

This section models separately the Treasury and the National Central Bank (NCB) participating in the Eurosystem (ES). This is as in e.g. Reis (2013, 2017), Bassetto and Messer (2013), Woodford (2016), Benigno and Nistico (2017) and Sims and Wu (2020) and can help us to understand the menu of fiscal and monetary policy instruments available to policymakers and how these instruments interact with each other. But, before we formalize things in subsections 2.6.2 and 2.6.3, it is necessary to put our work in the context of the literature on the nexus between fiscal, public finance and quantitative monetary policies in subsection 2.6.1.

2.6.1 On the nexus between fiscal, public finance and quantitative monetary policies

The literature on this nexus, departing from the benchmark model of Wallace (1981), has focused on three important questions: first, the role of the central bank as a fiscal actor and, specifically, what happens to the central bank when it attempts to alleviate fiscal burdens; second, the associated direct or indirect benefits for the government; third, the impact on the real economic activity (see e.g. Reis (2013, 2017), Benigno and Nistiko (2017), Sims and Wu (2020) and Blanchard and Pisani-Ferry (2020), while a rich review is in Walsh (2017, chapter 11.5)).

It is convenient to start with monetary policy. It used to be customary in macroeconomic models, especially between the 1970s and the global financial crisis of 2008, to focus on conventional monetary policy (a nominal policy interest rate, the nominal quantity of a monetary aggregate and the nominal exchange rate, which are dependent to each other) leaving aside balance sheet, or quantitative, policies which have to do with the total size of the central bank's balance sheet and the mix of assets and liabilities that the central holds (see Walsh (2017), section 11.5)). Related to this approach, it also used to be customary to lump the budget constraint of the Treasury and the budget constraint of the central bank into a single constraint, the so-called budget constraint of the consolidated public sector. As has been explained by e.g. Walsh (2017, chapter 11), Reis (2017) and Benigno and Nistico (2017), the origin of this tradition dates back to the baseline model of Wallace (1981) in which the size and mix of central bank's balance sheet does not affect the economy's real allocation. Besides, within this baseline model, regarding the ability of the central bank to alleviate fiscal burdens, resources from the central bank to the fiscal authorities either do not exist at all in equilibrium (as Reis (2017) puts it, when the central bank issues money to buy government bonds, one type of liability replaces another) or, when they exist, as it happens with seigniorage revenue, their real value is small in magnitude (see Sibert (2012) and Reis (2017)), although, it is worth clarifying here, that this presupposes that higher money growth is accompanied by higher inflation which is not always the case in the data.

However, the massive expansion in central bank balance sheets since the onset of the 2007-8 financial global crisis has forced a re-examination of the nexus between monetary, fiscal and public finance policies. Leaving aside conventional monetary policy instruments (whose independent use is reduced, or fully lost, in a small open economy with fixed exchange rates or in a currency union), balance sheet policies have been key elements of monetary policy around the world since 2007-8. All major central banks embarked on large-scale asset purchases (mainly in the form of government debt) and loans, and this has been financed by creation of money on the liability side of their balance sheets.[24] The ECB has not been an exception to this; the size of its balance sheet has increased by more than 200% between 2007 and 2019.[25]

As a response to these massive quantitative policies, the academic literature has added various financial frictions to the benchmark framework that result in departures from Wallace's neutrality property. Examples of such frictions that lead to asset pricing wedges include transaction costs, borrowing constraints, market segmentation, limited market participation,

[24] Historically, quantitative policies have always been key elements of standard monetary policy. It is only since the 1970s, that such policies have been regarded as unconventional. The 2007-8 crisis has simply forced a re-examination of this. See e.g. the papers presented in the workshop on "Threat of Fiscal Dominance?" organised by the Bank for International Settlements and the OECD in 2012 (BIS/OECD, 2012). See also the critical views in Ryan-Collins (2015).

[25] The assets (and hence the liabilities too) of the ECB were around 1,508,000 million euros in the end of 2007 and around 4,673,000 by the end of 2019 (see "Annual consolidated balance sheet of the ES" available at the ECB's site).

moral hazard, non-rational expectations, etc (see Walsh (2017, chapter 11) and Benigno and Nistico (2017) for reviews). Once we allow for such frictions, quantitative monetary policies can have fiscal implications and also affect the real economic activity.[26]

On top of this, as e.g. Sinn and Wollmershauser (2012), Sinn (2014) and Reis (2013, 2017) have pointed out, in a currency union like the ES, there can be extra routes through which quantitative monetary policies can alleviate fiscal burdens and relax national constraints even in the absence of financial frictions like the above. The currency union's central bank, like the ECB in the ES, can play a redistributive role by relaxing the fiscal and resource constraints of some regions and by tightening those of others. Specifically, Reis (2017, section 10) has argued that several of the ECB's policies (like the SMP, the provision of ELA and the way ECB's dividends are distributed to member-countries of the EZ) can belong to this category allowing for redistribution of real resources among governments and nations within the ES. A parallel literature (Sinn and Wollmershauser (2012) and Sinn (2014)) has argued that the issuance of *TARGET2* balances can work in the same redistributive way (*TARGET2* balances, which are particularly large in the case of Greece, are discussed and modeled below). Here, we will use a formal criterion that helps us to judge whether a quantitative, or balance-sheet, monetary policy can play a direct allocative role: it can, if, once market-clearing conditions have been taken into account, this policy instrument *remains as an item in the economy's resource constraint meaning its balance of payments*. According to this criterion, as we shall see below, purchases of government bonds by the ES beyond those purchased by the NCB, dividends given by the ES to the national government again beyond those transferred by its NCB, as well as the issuance of *TARGET2* liabililities by the NCB as part of its monetary base, can, at least in principle, play an allocative role and practically work like foreign public assistance that can replace private capital inflows from abroad as has been argued by Sinn (2014).

The rest of this subsection will embed the above facts in our model for the Greek economy. As said, the government will be separated into its two agencies, fiscal and monetary.

2.6.2 The Treasury (fiscal authorities)

The Treasury, or the fiscal branch of government, uses revenues from taxes on labor income, capital income and consumption, the issuance of government bonds and a direct receipt/dividend from the central bank to finance its various spending activities. This is standard; we will only differ in who can hold Greek public debt so as to embed the official fiscal bail out.

[26] Note that the Curdia and Woodford (2010, 2011) setup, also adopted here, is one out of several setups allowing for such a deviation from Wallace's benchmark case.

Public debt and its holders Let us define the real and per capita public debt at the end of period t as d_t. We assume that it can be held by four different types of creditors: domestic private agents/banks, the NCB in the ES,[27] foreign private agents/banks and foreign public institutions; the latter include EU institutions, like the ESM and other euro states, which will be labeled as "EU".[28] In the pre-crisis period (2001-2008), the public debt was mainly held by private (domestic and foreign) agents/banks, while during the years of the debt crisis most of the Greek public debt has changed hands and is now being held by the "EU" as part of Greece's various bailout programs (see subsection 3.2 below for data).

In particular, d_t is decomposed to:

$$d_t \equiv b_t^d + b_t^{ncb} + \frac{e_t p_t^*}{p_t} f_t^g + \frac{e_t p_t^*}{p_t} f_t^{eu} \tag{24a}$$

[27] We allow for government bond purchases by the NCB or the ECB for comparison to the literature (actually, most of government bond purchases are carried out by the NCBs rather than by the ECB itself; see e.g. Sinn (2014, chapter 8)). In the baseline numerical solutions below, we will set the fraction of Greek public debt owned by the NCB or the ECB at zero. This is for various reasons. For instance, these purchases are subject to the shares of NCBs in the ECB capital (this is the so-called capital key based on the population and size of the economy in each member country). In addition, NCBs and the ECB can purchase member-countries' government bonds in the secondary market only (see e.g. the early asset purchase programs like SMP and CBPP) which means that any beneficial effects (e.g. reductions in sovereign spreads) on public finances were indirect (see e.g. Gibson et al (2015) for Greece). On the other hand, in practice, things are not so clear. The ECB has supported Greek govenment bonds in several other ways. For instance, as Sinn (2014) has pointed out and as we further discuss in subsection 3.2 below, support to Greek private banks by the ECB has also been support to the government since private banks can use the loans given by the ECB to purchase bonds which are in turn used as collaterals for new loans from the ECB. In any case, as said, in our solutions we will set the fraction held by the NCB and the ECB at zero. Finally, regarding the model, note that we could add a secondary market for government bonds, in the sense that the NCB or the ECB purchase a part or all of the inherited (beginning-of-period) stock of bonds held by private agents/banks; we do not do it to avoid further additions to an already large model.

[28] As mentioned above, the official inter-governmental fiscal assistance to Greece since 2010 amounts to around 290 billion euros. This has been provided by the EFSF, the ESM as well as by other euro states. These are loans to countries in need, like Greece, after these countries sign a memorandum of understanding to implement an economic adjustment programme (see e.g. Sinn (2014, chapter 8)). In the case of Greece, most of this money has been used for public debt servicing payments which means the repayment of maturing government debt, the service of interest payments on existing government debt and various forms of bond exchanges that helped private banks and creditors to offload their holdings of Greek government bonds. As a result, today, around 70% of Greek public debt is owned by these European public institutions (see section 3.2 below for data and further details). Since these holdings are recorded as public debt (see e.g. the Greek Public Debt Management Agency and the Greek Ministry of Finance), we label this as Greek public debt held by the EU.

where, expressing them as fractions of total debt, we define:[29]

$$b_t^d \equiv \lambda_t^d d_t \tag{24b}$$

$$b_t^{ncb} \equiv \lambda_t^{ncb} d_t \tag{24c}$$

$$\frac{e_t p_t^*}{p_t} f_t^g \equiv \lambda_t^g d_t \tag{24d}$$

$$\frac{e_t p_t^*}{p_t} f_t^{eu} \equiv \lambda_t^{eu} d_t \tag{24e}$$

where $0 \leq \lambda_t^d, \lambda_t^{ncb}, \lambda_t^g, \lambda_t^{eu} \leq 1$ are the fractions of Greek public debt held respectively by domestic private agents/banks, the NCB, foreign private agents/banks and the EU, where $\lambda_t^d + \lambda_t^{ncb} + \lambda_t^g + \lambda_t^{eu} = 1$.[30] If the policy and rest-of-the-world variables, λ_t^{ncb}, λ_t^g and λ_t^{eu}, are exogenously given (they will be set as in the data), then residually $\lambda_t^d = (1 - \lambda_t^{ncb} - \lambda_t^g - \lambda_t^{eu})$.[31]

Government budget constraint Using this notation, the flow budget constraint of the government written in per capita and real terms is:

$$\begin{aligned}
&\overline{g}_t^{tr} + n^b \left[w_t^g l_{g,t}^g + \frac{p_t^h}{p_t} \left(g_{g,t}^g + g_{g,t}^i \right) + \frac{p_t^f}{p_t} m_{g,t}^g \right] + \\
&+(1+i_t^*) \frac{p_{t-1}}{p_t} \lambda_{t-1}^d d_{t-1} + (1+i^*) \frac{p_{t-1}}{p_t} \lambda_{t-1}^{ncb} d_{t-1} + \\
&+(1+i_t^*) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} \frac{p_{t-1}}{e_{t-1} p_{t-1}^*} \lambda_{t-1}^g d_{t-1} + \\
&+(1+i^*) \frac{p_{t-1}^*}{p_t^*} \frac{e_t p_t^*}{p_t} \frac{p_{t-1}}{e_{t-1} p_{t-1}^*} \lambda_{t-1}^{eu} d_{t-1} + \\
&+\frac{p_t^h}{p_t} \psi^g(.) \equiv d_t + \frac{T_t}{N} + rcb_t^g
\end{aligned} \tag{25}$$

where $\overline{g}_t^{tr}$ is the lump-sum transfer to each household, $n^b \left[w_t^g l_{g,t}^g + \frac{p_t^h}{p_t} \left(g_{g,t}^g + g_{g,t}^i \right) + \frac{p_t^f}{p_t} m_{g,t}^g \right]$ is the cost of state firms, $\psi^g(.)$ is a transaction cost function associated with the government's participation in the foreign capital market (defined right below), $\frac{T_t}{N}$ denotes tax revenues (defined right below) and rcb_t^g is a direct

[29] That is, if F_t^g denotes the nominal value of total public foreign debt expressed in foreign currency, $f_t^g \equiv \frac{F_t^g}{p_t^* N}$ is its per capita and real value

[30] As said, in our numerical solutions, we set $\lambda_t^{ncb} \equiv 0$.

[31] We have also experimented with the case in which the bonds bought by the EU have more than one period maturity so as to capture the longer maturity of these loans in reality. We report that adding multi-period safe loans by the EU (and the associated interest rates) does not change our main results. Perhaps this is because optimizing private agents are rational and forward-looking.

transfer/dividend from the central bank to the Treasury.[32] The rest of the terms capture interest payments on public debt where notice that the interest rates vary depending on the identity of the creditor. For instance, we assume that when the government borrows from the EU or the ES, it pays the constant world interest rate, i^*, only, while, when the government borrows from the market, is pays the country's interest rate, i_t^*, which inludes a premium (see subsection 2.8 below).

As in equation (4) above, we assume that the cost associated with participation in the foreign financial market takes the form:

$$\psi^g(.) \equiv \frac{\psi^g}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t}+\lambda_t^g d_t\right)}{\frac{p_t^h}{p_t}n^k y_{i,t}^h}-\overline{f}\right]^2 n^k y_{i,t}^h \tag{26}$$

where $\psi^g \geq 0$ is a transaction cost parameter associated with public borrowing from foreign markets.

Total tax revenues in real (but not per capita) terms are defined as:

$$\frac{T_t}{N} \equiv \tau_t^c[n^k(\frac{p_t^h}{p_t}c_{k,t}^h+\frac{p_t^f}{p_t}c_{k,t}^f)+n^w(\frac{p_t^h}{p_t}c_{w,t}^h+\frac{p_t^f}{p_t}c_{w,t}^f)+$$

$$+n^b(\frac{p_t^h}{p_t}c_{b,t}^h+\frac{p_t^f}{p_t}c_{b,t}^f)]+\tau_t^y n^k w_t^k l_{k,t}+\tau_t^y n_t^{w,e}n^w w_t^w l_{w,t}+$$

$$+\tau_t^y n^b w_t^g l_{b,t}+\tau_t^\pi n^k\left[PR_t\frac{p_t^h}{p_t}y_{i,t}^h-w_t^w\frac{n_t^{w,e}n^w}{n^k}l_{w,t}-w_t^k l_{k,t}-\frac{p_t^f}{p_t}m_{i,t}^f\right] \tag{27}$$

One of the policy variables must follow residually to close the Treasury's budget constraint in (25); this is defined below after we present the budget constraint of the NCB.

2.6.3 The National Central Bank (NCB) in the Eurosystem (ES)

Before we introduce the Greek NCB, we need to clarify how the balance sheet of a NCB participating in the ES is related to the consolidated balance sheet of the ES.

The ES and its NCBs The financial statement and the budget constraint of the ECB is not different from that of a standardized central bank.[33]

[32] See e.g. Walsh (2017, chapter 4), Reis (2013, 2017), Bassetto and Messer (2013), Woodford (2016) and Benigno and Nistico (2017). In the ES, like with the purchase of government bonds, there are rules applying to the amount of dividends distributed by the ECB to each national fiscal authority. However, see e.g. Gros (2016) and Reis (2017, section 10) for details and perhaps exceptions in the case of Greece.

[33] See e.g. "Annual consolidated balance sheet of the ES" and "User guide on the ES consolidated weekly financial statement" (available at the site of the ECB). For the conduct of monetary policy in the ES, see e.g. "The monetary policy of the ECB" (ECB, 2011, chapter 4).

In other words, as is typically the case with central banks (see e.g. Reis (2009, 2013) and Whelan (2014, section 2.1)), the assets side of the balance sheet of the ECB consists mainly of foreign currency, loans to credit institutions[34] and securities.[35] The liabilities side, on the other hand, consists mainly of banknotes in circulation (held by the non-bank public), reserves which are also called current accounts (held by private banks at the central bank) and government deposits; these are also the main items of the monetary base of the ES.

However, the consolidated balance sheet of the ES shows assets and liabilities of the ES NCBs vis-à-vis third parties only. In other words, it does not include credits and debits between the ES's NCBs, known as Intra-Eurosystem claims and liabilities and recorded respectively as *TARGET2* assets and *TARGET2* liabilities in the financial statements of the individual NCBs participating in the ES. As first pointed out by Sinn and Wollmershauser (2012) and Sinn (2014), and further studied by Whelan (2014, 2017), Perotti (2020) and many others, these are net bilaterals positions vis-a-vis the ES, which means that the NCB of a member country transferring money abroad records a *TARGET2* liability to the rest of the ES, while the NCB of a member country receiving the money from abroad records a *TARGET2* asset. These *TARGET2* balances cancel each other out at aggregate ES level (this is by construction) and therefore do not appear in the consolidated balance sheet of the ES as described above.[36] However, they do appear in the balance sheets of the individual NCBs in the sense that they enter as an extra item of liabilities for a country with Intra-Eurosystem liabilities like Greece (see e.g. Whelan, 2014, Table 2) or as an extra item of assets for a country with Intra-Eurosystem claims like Germany (see e.g. Whelan, 2014, Table 3). In other words, for a country like Greece, *TARGET2* liabilities have become a part of the monetary base created by its NCB in accordance with the rules of the ES.[37]

[34]This includes main refinancing operations (MROs), longer-term refinancing operations (LTROs), marginal lending facilities, etc. It also inludes emergency liquidity assistance (ELA) to private banks with severe liquidity problems.

[35]This includes the covered bond purchase program (CBPP), the securities markets program (SMP), the asset purchase progrmme (APP) since 2015, etc.

[36]See e.g. Whelan (2014, 2017) and Perotti (2020) for the mechanics of the *TARGET2* system and how assets and liabilities of both private banks and NCBs change in response to various changes like moving money from a bank account in country A to a bank account in country B. As Sinn (2014, p. 187) says, "the outflow of money from Greece goes hand-in-hand with ... the inflow of money into Germany, ... in turn, leads to additional liquidity that German banks do not need and which they therefore choose to lend to the Bundesbank with the effect that the money is removed from the economy".

[37]As Sinn (2014) has pointed out, a natural question to ask is whether NCBs in the ES can freely issue liabilities in euros, namely, print banknotes, issue reserves and create *TARGET2* liabilities. The answer is a qualified "yes" (see e.g. Sinn (2014) and Whelan (2014, 2017)) to the extent that they act according to the rules defined by the ECB council. As said already, the latter has loosened the requirements for private banks obtaining loans,

Looking at the data, as is well recognized, there was an explosion of *TARGET2* balances after 2008.[38] For the ES as a whole, *TARGET2* balances were very small prior to the crisis but have increased substantially since then; they were 186 billion euros in May 2008, 416 billions in July 2011, 1.09 trillion in August 2012 and 1.24 trillion in September 2017 (see Whelan (2017, Figure 1)). In the case of Greece, *TARGET2* liabilities were, for instance, 105 billion euros in 2011 which translates into 105/168=62% of the total liabilities of the Greek NCB or 105/207=51% of GDP, and 94 billion euros in 2015, which translates into 94/163=58% of the total liabilities of the Greek NCB or 94/177=53% of GDP.[39] Actually, as we shall see in the next section, in the case of Greece, *TARGET2* liabilities have been by far the largest item of liabilities, and hence of the monetary base of the Greek NCB, in every year between 2008 and 2017 (included).

Before we move on, it is worth recalling that, since the publication of the seminal paper by Sinn and Wollmershauser (2012), there has been a heated debate at both academic and policy circles over the role of these assets and liabilities. Opinions have ranged from *TARGET2* being an innocent and mechanical protocol of the ES to being a hidden bailout of the periphery EZ countries in trouble (for the latter see Sinn (2014)). Today, to the best of our understanding, there is a kind of consensus, in the sense that the enormous magnitude of *TARGET2* balances during the years of the debt crisis: (a) is closely related to fears of default and a euro break up (b) is closely related to loans to private banks and the ECB's balance sheet policies in general (c) facilated a capital flight from the periphery to the core (d) is not clearly timed to current account deficits in the periphery (see e.g. Whelan (2014) and Perotti (2020) for such a consensus).

Balance sheet and budget constraint of the Greek NCB Given the above facts, on the side of assets of the Greek NCB, we will include loans to private banks and government securities, while, on the side of liabilities, we will include banknotes in circulation and *TARGET2* liabilities. These are the largest asset and liabilities items in the financial statemenst of the Greek NCB (see subsection 3.2 for data).[40] Then, the budget constraint of

has provided funding for longer periods, has allowed for ELA against collateral that was not included in ECB's list, etc.

[38] For *TARGET2* data across euro area countries, see e.g. Whelan (2014, 2017). See also e.g. "Target balances of participating NCBs" and "The ECB's asset purchase programme and TARGET balances: monetary policy implementation and beyond" (available at the ECB's site).

[39] As the data show (e.g. Whelan (2014, 2017)), the same happened in other periphery countries of the EZ. For instance, in Ireland, *TARGET2* liabilities peaked at 91% of GDP in 2010 (see also Lane (2014) for Ireland).

[40] We do not include reserves held by private banks at the Greek NCB simply because they are small in magnitude in the data. This is different from the ES level where most of the increase in the monetary base of the ES has been in the form of reserves (see "Annual consolidated balance sheet of the ES" available at the ECB's site). See also e.g. Reis

the NCB linking changes in assets and liabilities is (written in real and per capita terms):

$$n^k z_{p,t} + \lambda_t^{ncb} d_t + rcb_t^g \equiv$$
$$\equiv \left(h_t^n - \frac{p_{t-1}}{p_t} h_{t-1}^n \right) + \left(TARG_t - \frac{p_{t-1}}{p_t} TARG_{t-1} \right) +$$
$$+ n^k (1+i_t^z) \frac{p_{t-1}}{p_t} z_{p,t-1} + (1+i_t^*) \frac{p_{t-1}}{p_t} \lambda_{t-1}^{ncb} d_{t-1} \tag{28}$$

where $n^k z_{p,t}$ is the end-of period loans to private banks, $\lambda_t^{ncb} d_t \equiv b_t^{ncb}$ is the end-of-period government bonds purchased by the NCB (however, for the reasons explained in subsection 2.6.2 above, we will set $\lambda_t^{ncb} \equiv 0$ in our baseline solutions), rcb_t^g is the direct transfer/dividend from the NCB to its government (as said above, this is the NCB's balance-sheet earnings rebated to the Treasury), h_t^n denotes the end-of-period stock of banknotes in circulation and $TARG_t$ denotes the end-of-period stock of *TARGET2* liabilities (for notational simplicity, which is also close to the data, we assume that the refinancing rate on $TARGET2$ balances is zero). In other words, in our model, $h_t^n + TARG_t \equiv MB_t$ is the monetary base of the Greek NCB within the ES (these variables are written in real and per capita values).

In equilibrium, in our model, banknotes in circulation will be equal to the currency demanded by the public for liquidity-providing services, namely, $h_t^n = n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t}$ in each t. In this case, *TARGET2* liabilities are the difference between MB_t and $n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t}$. In other words, to the extent that the monetary base of the NCB exceeds the amount of currency held by the public for liquidity services,[41] or, loosely speaking, to the extent that the funds made available by the NCB are not only used to hold a larger stock of money balances, the country has a *TARGET2* liability to the rest of the ES.[42]

We should make two further points here regarding *TARGET2* liabilities. First, they are possible because, in a currency union (CU), the money market clears at a CU level rather than at local/national level. Second, the way in which these cross-country liabilities affect the real economy, and how they can be used, will become clear below when we present the country's balance of payments (as said in subsection 2.6.1 above, this is our formal criterion to judge if a balance-sheet monetary policy item affects national resources).

One of the monetary policy variables must adjust residually to close the budget constraint in (28); this is defined below jointly with the fiscal policy variable that closes the Treasury's budget constraint in (25).

(2009) and Sims and Wu (2020) for liabilities of the FED, where reserves have played a big role.

[41] Or, equivalently, since assets are equal to liabilities by definition, to the extent that the claims of the NCB on its private sector exceed the amount of currency held for liquidity services.

[42] We are grateful to Hans-Werner Sinn for comments on this issue. Any errors are ours.

2.6.4 Budget constraint of the consolidated public sector

To the extent that the transfer/dividend from the NCB to its government, rcb_t^g, is free and can be treated as an endogenous variable, we can combine the budget constraint of the Treasury in (25) and the budget constraint of the NCB in (28) into a single constraint, the budget identity of the consolidated public sector (see e.g. Reis (2017) and Benigno and Nistico (2017) for details). That is, by also using the market-clearing condition $h_t^n = n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t}$, we get (written in real and per capita terms):

$$\begin{aligned}
&\overline{g}_t^{tr} + (1+i_t^*)\frac{p_{t-1}}{p_t}\lambda_{t-1}^d d_{t-1} + \\
&+(1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^g d_{t-1} + \\
&+(1+i^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^{eu} d_{t-1} + \\
&+n^b\left[w_t^g l_{g,t}^g + \frac{p_t^h}{p_t}\left(g_{g,t}^g + g_{g,t}^i\right) + \frac{p_t^f}{p_t} m_{g,t}^g\right] + \\
&+\frac{p_t^h}{p_t}\frac{\psi^g}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t} + \lambda_t^g d_t\right)}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{f}\right]^2 n^k y_{i,t}^h = (\lambda_t^d + \lambda_t^g + \lambda_t^{eu}) d_t + \frac{T_t}{N} + \\
&+n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t} - \frac{p_{t-1}}{p_t}(n^k h_{k,t-1} + n^w h_{w,t-1} + n^b h_{b,t-1}) - \\
&-n^k\left(z_{p,t} - (1+i_t^z)\frac{p_{t-1}}{p_t} z_{p,t-1}\right) + \left(TARG_t - \frac{p_{t-1}}{p_t} TARG_{t-1}\right) \qquad (29)
\end{aligned}$$

where all variables have been defined above.

Inspection of the above constraint confirms some standard properties, but it also reveals some distinct features of the ES. Regarding standard properties, the NCB's purchase of government bonds, $\lambda_t^{ncb} d_t$, as well as the provision of transfers/dividends to its own government, rcb_t^g, do not appear in the consolidated government budget constraint. As said above, this is simply because when the NCB transfers resources to its own government, or vice versa, one type of liability replaces another (see Reis (2009, 2013, 2017) and also Bassetto and Messer (2013), Woodford (2016) and Benigno and Nistiko (2017)). As a consequence, the NCB can only generate revenue for its government through the real value of seigniorage, $\left(\frac{H_t^n - H_{t-1}^n}{p_t} \equiv h_t^n - \frac{p_{t-1}}{p_t} h_{t-1}^n\right)$, whose size is an empirical matter. This is standard. On the other hand, the same constraint reveals how, in a currency union, a single central bank like the ECB, that faces different fiscal authorities, can redistribute resources and thereby alleviate the fiscal burden of member-countries in need (see Reis (2017, section 10)). In particular, as the above constraint reveals, this can be done via purchases of government bonds beyond those purchased by the NCB (see the term $\lambda_t^{eu} d_t$ which, as said, can, in principle at least, include ECB's holdings) and by the permission to issue *TARGET2* liabilities to the extent that this issue is beyond the amount of currency held by the public for liquidity services. As we shall see, the very same terms will also appear in the balance of payments presented below. Finally, it is worth adding that had we allowed for direct transfers/dividends by the ECB beyond those provided by the NCB, these transfers/dividends would also remain in the budget constraint of the consolidated public sector (as well as, in the balance of payments below) and hence could play a redistributive allocative role similar to that played by $\lambda_t^{eu} d_t$ and *TARGET2* liabilities.

As in (25) and (28) above, one policy variable must adjust residually to close (29); this is defined right below.

2.6.5 Fiscal-monetary policy regime

By policy regime, we typically mean a choice of which policy variables are set by the policy authorities and which have to follow endogenously/residually to accommodate the policy decisions made (see e.g. Reis (2009)).

Inspection of the budget constraints of the Treasury and the NCB, in (25) and (28) respectively, reveal the various options available to fiscal and monetary authorities or, equivalently, the possible policy regimes. In other words, once one allows for a more realistic menu of monetary policy instruments as we have done here (in particular, assets and liabilities of the NCB and the associated policy interest rates), there is a wide range of policy regimes even in a small open economy within a currency union or with fixed exchange rates.

Here, to capture the fiscal austerity mix adopted by the Greek governments, the shutting out of the country from international private capital markets, as well as the official fiscal bailouts and the plethora of accommodative quantitative monetary policies followed by the ECB towards Greece during the sovereign debt crisis years, we will set all tax rates, all types of government spending as shares of GDP, the public debt-to-GDP ratio jointly with its decomposition to various holders (including the foreign public institutions, labeled as EU in our model), as they have been in the actual data over the crisis years, and then assume that the transfer/dividend from the NCB to the government, rcb_t^g, is residually determined by the NCB's budget constraint in (28), which implies, as said above, that the budget constraint of the NCB and the budget constraint of the Treasury can be merged into the single consolidated budget constraint in (29), and, in turn, assume that the latter is satisfied by adjustments in the monetary base. Actually, to the extent that the monetary base consists of banknotes in circulation and *TARGET2* liabilities, $MB_t \equiv h_t^n + TARG_t$, where the banknotes in circulation are determined by the currency demanded by the public for liquidity-providing services, $h_t^n = n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t}$, endogeneity of the change in the monetary base practically means endogeneity of the cross-border liquidity term, $\left(TARG_t - \frac{P_{t-1}}{P_t} TARG_{t-1}\right)$. In other words, we assume that the ECB has been following an accommodative policy towards Greece, in the sense that it has increased its monetary base and specifically the issuance of *TARGET2* liabilities so as to accommodate the rest of policies as well as the macroeconomic developments occurring at the same time. At least at regional/national level, this is a regime of fiscal dominance meaning active fiscal policy and passive monetary policy (see e.g. Walsh (2017, chapter 4)).[43] The list of endogenous variables and the exogenously set policy instruments in the final macroeconomic system is presented in detail in Appendix C of the supplementary file.

2.7 Balance of payments

If we add up the budget constraints of all agents, we get the country's resource constraint or its balance of payments (written in real and per capita terms):

$$
\begin{aligned}
&\frac{p_t^f}{p_t}\left(n^k c_{k,t}^f + n^w c_{w,t}^f + n^b c_{b,t}^f + n^k m_{i,t}^f + n^b m_{g,t}^g\right) - \frac{p_t^h}{p_t} c_t^{f*} + \\
&+(1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t} n^k f_{k,t-1} + \\
&+(1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^g d_{t-1} + \\
&+(1+i^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^{eu} d_{t-1} + \\
&+\frac{p_t^h}{p_t}\frac{\psi^p}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t} + \lambda_t^g d_t\right)}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{f}\right]^2 n^k y_{i,t}^h + \\
&+\frac{p_t^h}{p_t}\frac{\psi^g}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t} + \lambda_t^g d_t\right)}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{f}\right]^2 n^k y_{i,t}^h = \\
&= \frac{e_t p_t^*}{p_t} n^k f_{k,t} + \lambda_t^g d_t + \lambda_t^{eu} d_t + \left(TARG_t - \frac{p_{t-1}}{p_t} TARG_{t-1}\right) \qquad (30)
\end{aligned}
$$

Inspection of the balance of payments reveals the cross-country redistributive role that the ECB can play at least in principle. This can be done

[43] As Reis (2019) points out, fiscal dominance at the EZ level has been avoided. On the other hand, monetary accommodation (via e.g. *TARGET2* balances, purchase of national government bonds, sharing of ECB's dividends, provision of ELA, etc) has worked like fiscal dominance in those member-countries hit by the crisis.

by purchases of government bonds beyond those purchased by the NCB (see the term $\lambda_t^{eu} d_t$ which, as said above, can include ECB's holdings) and by allowing the NCB to issue excess liquidity in the form of *TARGET*2 liabilities to the rest of the ES (see the term $TARG_t - \frac{p_{t-1}}{p_t} TARG_{t-1}$, which, also as said above, becomes possible when the monetary base of the NCB exceeds the amount of currency held by the public for liquidity services).[44] As is revealed by (30), these items can be used to finance imported goods, to repay foreign debt or to finance investments abroad.

A final clarification of the role of *TARGET2*: As pointed out by Sinn (2014, p. 180), our term $\left(TARG_t - \frac{p_{t-1}}{p_t} TARG_{t-1}\right)$ is the increase in "the amount of central bank credit that has been issued *in excess* of liquidity needs for transactions within the NCB's national jurisdiction". Had the economy been closed, or had we have a small open economy with a national currency, this term could not be present in the balance of payments; there could not be any use of extra self-created money in those cases. Here, it becomes possible thanks to participation in a currency union which means that the money market clears at currency union level, rather than at national level within each jurisdiction, and that the currency issued (euro) works like an "international" currency at least within the EZ.[45]

2.8 Country's interest rate

Following most of the literature on small open economies (e.g. Schmitt-Grohé and Uribe (2003) and Uribe and Schmitt-Grohé (2017)), we assume that the interest rate at which the country (meaning both private and public agents) borrows from abroad, i_t^*, is public debt-elastic (except in the case in which it borrows from non-market institutions like the EU). In particular, we use the functional form:

$$i_t^* = i^* + \psi^* \left(\exp\left(\frac{d_t}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{d} \right) - 1 \right) \tag{31}$$

where ψ^* is an interest-rate premium parameter and the parameter $\overline{d} \geq 0$ is a threshold value for the public debt-to-GDP ratio above which country premia emerge (for details and references, see Philippopoulos et al (2017a)).

[44] The same can happen, as said above, via direct transfers/dividends provided by the ECB beyond those provided by the country's NCB.

[45] To make the point clearer, consider a miniature version of our model without financial intermediaries, a government or foreign assets. The budget constraints of the private sector and the NCB are respectively $c_t + \Delta h_t = y_t + \Delta z_t$ and $\Delta z_t = \Delta MB_t = \Delta h_t + \Delta TARG_t$, where h_t is currency held by the private agent, z_t is a loan from the NCB (assume a zero interest rate), MB_t denotes the monetary base, $\Delta x_t \equiv x_t - x_{t-1}$ and the rest are obvious and are as in the paper above. Then, adding them up, the economy's resource constraint or its balance of payments is $c_t = y_t + \Delta TARG_t$. We are grateful to Hans-Werner Sinn for this model specification. Note that if the currency is national, so that the money market clears at national level, $h_t = z_t$ and hence $TARG_t = 0$ at any t.

2.9 How we will work from now on

Market-clearing conditions and the macroeconomic system are respectively presented in Appendices B and C of the supplementary file. The macroeconomic system consists of 51 equations in 51 variables. This is given the paths of the exogenously set policy variables and the degree of property rights, whose values will be set as in the data.

In the next sections, we will parameterize the model, present the data and in turn solve the system numerically. Our quantitative analysis will consist of the following steps. First, after presenting parameter values and Greek data, we will get a stationary solution using data of the year 2008. As we shall see, this solution can match reasonably well the main features of the data before the eruption of the crisis and can thus serve as a departure point in what follows. This is in section 3. In turn, departing from the 2008 solution, sections 4 and 5 will study the period 2008-2019 which are the years of the Greek sovereign debt crisis. In particular, we will feed the model with the time-series of our exogenous forces (changes in policy variables, institutional quality, etc) as they have been in the time-series in the data. This will allow us to provide a quantitative assessment of the main drivers of the Greek depression between 2008 and 2016. In these solutions, along the transition of the economy to its new stationary equilibrium, we will assume that after 2019 (this is the last year that data for all exogenous variables are available) the model's exogenous variables remain as in 2019. But, we will also experiment with various counter-factual scenarios since 2008 that could have possibly made the economic downturn milder or worse. Finally, departing from the 2019 solution, in section 6, we will study the new economic crisis triggered by the convid-19 pandemic.

We will assume that all this is common knowledge so that we solve under perfect foresight using a Newton-type non-linear method implemented in DYNARE.

3 Parameterization, data and solution for 2008

To make quantitative predictions, we need to solve the model numerically. In subsection 3.1, we will present structural parameters related to technology and preferences. In subsection 3.2, using relevant data from Greece, we will specify the driving forces of the model, namely, the time paths of the exogenously set policy variables and the degree of property rights. This will also provide empirical support for some key assumptions of the model. Subsection 3.3 will then present the stationary solution of the model when we use data for the year 2008 which was the last year before the sovereign debt crisis in Greece.

3.1 Parameter values

Regarding structural parameters for technology and preferences, for most of them, we will use commonly employed values, while the rest will be calibrated so as the model to mimic some key Greek statistics. Parameter values are listed in Table 1. We report at the outset that our main results are robust to changes in these baseline parameter values at least within reasonable ranges.

Starting with preference parameters, the time discount factors of savers and borrowers, β and β^k, are set at 0.99 and 0.98 repectively so as to give a lending interest rate above the saving interest rate. The weights given to private consumption, leisure and real money holdings, μ_1, μ_2 and μ_3 in households' utility function, are set respectively at 0.40, 0.55 and 0.03, while the remaining, 0.02, goes to utility-enhancing public goods/services; these values produce work hours, etc, within usual ranges. The degree of preference of home goods over foreign goods, ν, is set at the neutral value of 0.5; this value also contributes to delivering reasonable ratios of home to foreign goods in households' consumption spending.

Continuing with technology parameters, in the production function of private goods, the exponent of labor, $1-\alpha$, is set at 0.6, while, the rest, $a = 0.4$, is the exponent of the CES term that includes capital and imported goods. In the same production function, the contribution of productivity-enhancing public goods/services to private production, σ, is set at 0.1. The work productivity parameters of entrepreneurs and workers in the private good production function, A^k and A^w, are set at 3 and 2 respectively; this difference produces a skilled wage premium within usual ranges. In the private firm's production function, the parameter measuring the intensity of capital vis-a-vis imported goods, χ^p, as well as the parameter measuring the substitutability between capital and imported goods, op, are both set at 0.5; the same value of 0.5 is used for χ^g and og in the state firm's production function. Also in the state firms' production function, the Cobb-Douglas exponents of public capital and public employment, θ_1 and θ_2, are set respectively at 0.3045 and 0.6, which correspond to payments for public investment and public wages, expressed as shares of total public payments to all inputs used in the production of public goods, as they are in the data (for similar practice, see e.g. Economides et al (2014) and the references therein); in turn, the Cobb-Douglas exponent of goods purchased from the private sector, $1-\theta_1-\theta_2$, follows residually. Both private and public capital depreciation rates, δ and δ^g, are set at 0.05. Similarly, both TFP parameters (in the private and in the public sector production functions) are normalized at 1 (note that public sector efficiency, and why it may differ from private sector efficiency, is crucial but is not an issue in this paper). In the baseline simulations, the Dixit-Stiglitz parameter capturing imperfect competition in product markets, θ, is set at 0.75; this is close to the literature (see e.g.

Eggertsson et al (2014)) and produces a profit ratio around 10%. In the rent-seeking technology, the power coefficient is set at 0.5, which is common across all types of agents, while the effectiveness parameters of public employees, entrepreneurs and workers, Γ^b, Γ^k and Γ^w, are set respectively at 1.3, 1 and 0.7 to reflect their relative political power in rent extraction.

The transaction cost parameters associated with capital changes in the firm's problem, private bank loans to firms and NCB loans to private banks, ξ^k, ξ^l and ξ^z, are all set at 0.3, while the "anti-transaction" cost parameter associated with government bonds held by private banks, ξ^b, is simply set at zero. The Rotemberg-type parameter associated with price changes in the firm's problem, ξ^p, is set at 3. The two transaction cost parameters associated with private and public participation in the foreign capital market, ψ^p and ψ^g, are set at 0.5. The risk premium parameter in the debt-elastic interest rate rule, ψ^*, is set at 0.05; this belongs to usual ranges and also produces a foreign debt to GDP ratio as in the data when the crisis erupted. The fixed world interest rate, i^*, is set at 1%. The two parameters in the function of exports, Θ and ϑ, are set at 0.5 and 2 respectively; these values contribute to producing a trade deficit close to the data. The threshold values of public debt and foreign debt as shares of GDP, above which problems start, are set at 1.1 and 0.8 respectively which are values close to those in Reinhart and Rogoff (2009). The parameters in the two inequality borrowing constraints, ρ^l and ρ^z, are set at 0.5.

Finally, the population fractions of public employees, n^b, and self-employed or entrepreneurs, n^k, are set at 0.2 and 0.2 respectively as in the data, so that the fraction of workers, n^w, follows residually at 0.6.

Table 1: Baseline parameterization

3.2 Data and facts during the Greek sovereign debt crisis 2008-2019

In this subsection, we present the data used for the modelling of the exogenous variables in the numerical solutions. In doing so, we will also shed light to some relatively unnoticed features of the Greek sovereign debt crisis. The same data will support some key assumptions of our model.

As has already been said in the Introductory section above, there were at least three notable developments in the Greek economy after 2008. First, Greece resorted to international financial assistance provided by other EU countries, European institutions (EFSF, EFSM, ESM and the ECB) and the IMF. Second, as a condition for the assistance received, Greece was forced to take severe fiscal austerity measures and to promise the implementation of structural reforms in product and labor markets. Third, the fiscal austerity measures taken and the severe economic downturn that followed were accompanied by a sharp deterioration in institutional quality. These three distinct developments are the main driving forces in our model; the rest is structural reforms captured by simple changes in parameter values like the Dixit-Stiglitz product substitutability parameter (see below). In what follows, we briefly comment on the main driving forces and present the data used in our solutions over 2008-2019. As said above, the new covid-19 crisis will be studied in section 6.

3.2.1 International financial assistance (fiscal and monetary)

In the case of Greece, over the years of the debt crisis 2008-2019, official fiscal rescue operations have been expressed by three bailouts. The first took place in 2010-11 through the Greek Loan Facility, the second in 2012-2015 through the EFSF and the third in 2015-2018 through the ESM (see ESM (2018) for details). These programs were completed in August 2018 so the country is no longer reliant on ongoing official rescue loans. The total amount received by Greece since 2010 is around 290 billion euros which is the largest financial assistance package in history. As explained above, most of this has been used for public debt servicing payments.[46] As a result, today, close to 70% of Greek public debt is owned by public institutions (member states of the euro area, EFSF, ESM, ECB, etc).

Data for public debt, as well as the fractions of it held by public institutions, λ_t^{eu}, and foreign private investors/banks, λ_t^{g}, over time, are reported in Table 2, while the rest is in the hands of domestic private investors/banks, λ_t^{d}. In other words, as explained in subsection 2.6.2 above, we set $\lambda_t^{ncb} \equiv 0$ and $\lambda_t^{d} = (1 - \lambda_t^{ncb} - \lambda_t^{g} - \lambda_t^{eu})$. Notice that, in our solutions, the official fiscal bailouts are captured by setting the time-paths of total public debt to GDP, as well as its decomposition among the four holders, as they are in these data.

Table 2: Greek public debt and its main holders

Regarding monetary policy,[47] conventional responses by the ECB included a sharp reduction of policy interest rates, while non-conventional responses, focusing on those related to Greece and other EZ periphery countries in trouble, included a fixed rate full allotment loan policy to private

[46] See e.g. Bortz (2015), Rocholl and Stahmer (2016) and ESM (2017, 2018) for a detailed decomposition, that is, how the loans were used by Greece in the three official bailout programs. Most of the rest of the bailout money has been used to finance the cost of the haircut in March 2012 (this is the so-called private sector involvement (PSI), according to which privately held governments bonds took a 53.5% cut of their face value, which corresponds to 107 billion euros reduction, although, with an exchange of EFSF bonds, the overall debt burden decreased by 52 billion euros only) and the cost of bank recapitalization.

[47] For the ECB's response to the crisis, see e.g. Sinn (2010, 2014), ECB (2011), Sibert (2012) and De Grauwe (2016).

banks subject to lower collateral standards, the extension of maturity of liquidity provision, the issuance of ELA credit under the guarantee of the NCB to help private banks overcome liquidity crises and probably insolvency problems, and the purchase of collateral themselves on the secondary market (e.g. the Securities Markets Programme, SMP, in 2011) to support their market price and keep the interest rates relatively low.[48] Furthermore, when uncertainty got worse in the summer of 2012, the ECB announced that it would buy an unlimited amount of government bonds in the secondary market if that would become necessary (this is the Outright Monetary Transactions, OMT, program), under the condition that the ECB is actively involved, as part of the so-called Troika meaning the EC, the IMF and the ECB, in the monitoring of budgetray policies in the countries in need (see e.g. De Grauwe (2016, pp. 174-175, 210)). Eventually, in early 2015, the ECB decided to start officially its QE asset-purchasing program although this did not apply to Greece being under a memorandum of understanding at that time. In addition, since the very early days of the debt crisis, there has been a big rise in *TARGET2* liabilities as studied in some detail in subsection 2.6 above.

Tables 3a and 3b present the main items in the balance sheets of the Bank of Greece. As can be seen, *TARGET2* balances have the lion's share of liabilities, while loans to private banks are the biggest item on the asset side. Recall that, in our model, the accommodative and complex role played by the ECB during the Greek debt crisis is captured by treating the change in *TARGET2* liabilities, $\left(TARG_t - \frac{P_{t-1}}{P_t}TARG_{t-1}\right)$, as an endogenously determined variable (see subsection 2.6.5 above). Also, for simplicity, we will set the nominal interest rate on loans from the NCB to private banks, i_t^z, at zero, and, as explained in subsection 2.6.3, the same applies to the nominal interest rate on *TARGET2* liabilities to the rest of the ES. On the other hand, the role of the ECB during the new covid-19 crisis is analysed in section 6 below.

Table 3a: Bank of Greece's assets

Table 3b: Bank of Greece's liabilities

[48]Some details: In addition to its active support to the banking system, the ECB, during 2011-2012, bought a limited amount of government securities of southern euro zone countries including Greece under SMP; see e.g. Sinn (2014, pp. 147, 259) and De Grauwe (2016, pp. 210-2). In the case of Greece, since the collaterals, used for this credit, mainly consisted of Greek government bonds (i.e. the commercial banks were the largest holders of government bonds), these measures effectively constituted an indirect government financing through the ECB; see e.g. Sinn (2014, pp. 151, 158) and De Grauwe (2016, pp. 173-175, 210-2). Besides, as has been noted by several authors (see e.g. Sinn, 2014), there is no real difference between the controversial SMP and massive lending to private banks from the ECB, since private banks can use the extra liquidity to invest in bonds of distressed governments which can in turn be used as collaterals in new credit from the ECB.

3.2.2 The stick: fiscal austerity and structural reforms

The above described financial aid was provided under the condition that Greece undertakes a severe fiscal austerity plan (a description of the Greek austerity plan is in e.g. Alesina et al (2019, chapter 8) and Alogoskoufis (2019)). Irrespectively of the arguments for and against it, the fact is that Greece adopted a comprehensive fiscal consolidation plan including a high tax burden and cuts in various items of public spending. Data for total government revenue and expenditure are reported in Table 4a, while data for effective tax rates (τ^y and τ^c) and the main categories of public spending as shares of GDP (s^i, s^g, s^{tr} and s^w) are reported in Table 4b (the GDP share of public spending on imported goods, s^m, is arbitrarily set at 0.03). These time-series will be used for the exogenously set fiscal and public finance variables in our numerical solutions.

Table 4a: Total government revenue and expenditure
Table 4b: Fiscal (spending-tax) policy variables

It should also be added here that, in addition to the fiscal austerity measures taken, Greece had adopted the commitment to maintain a primary surplus of 3.5% of GDP until 2022 and around 2% in the following years (this has been postponed until the end of the new covid-19 crisis). It has also promised to implement structural (non-fiscal) reforms in labor and product markets, as well as in the functioning of its public sector (see e.g. ESM, 2018). Such much-needed reforms however still lag behind (see e.g. Rocholl and Stahmer (2016) and Masuch et al. (2018)), despite the optimism expressed by the European Commission (2019) in its enhanced surveillance report on Greece. In any case, as said above, structural reforms in the product market can be easily captured by changes in the Dixit-Stiglitz parameter, θ (see next section).

3.2.3 Institutional quality

Figure 1a presents our index for the enforcement of property rights in Greece. This index has been constructed as the average of three sub-indices: "the rule of law", "regulatory quality" and "political stability and absence of violence/terrorism", which are three variables commonly used for the construction of a measure of property rights protection (the data have been rescaled from 0 to 1). This index will be used for the time-series of the exogenous PR_t in our numerical solutions.

Figure 1a: Property rights in Greece

Since institutional quality is a relative thing, for comparison, we also present some cross-country data. The same three sub-indices, now in various

EZ countries including Greece, are shown in Figures 1b, 1c and 1d (these Figures have been borrowed from Christou et al. (2020)). As can be seen, Greece, not only has always been a country with poor institutional quality, but, to make it worse, it experienced a sharp deterioration after 2008, as has also been pointed out by e.g. Micossi (2016), Papaioannou (2016) and Masuch et al. (2018).

Figure 1b: Rule of law, comparison to other countries
Figure 1c: Regulatory quality, comparison to other countries
Figure 1d: Political stability and absence of violence/terrorism, comparison to other countries

3.3 Solution for the pre-crisis year 2008

Using the parameter values listed in Table 1 and data of the year 2008, the stationary solution of the model is reported in Tables 5a and 5b (we report some key variables only). In this solution, variables do not change (so it can be thought as the "trend" of the Greek economy before the global financial crisis) and all exogenous variables have been set as in the data of the year 2008. The solution is in line with data averages over 2000-2008 and can thus provide a reasonable departure for the changes that have been taking place since 2009 and are studied in the next sections. In particular, the solution does a relatively good job at mimicking the position of the country in the international capital market, as well as the consumption-investment behavior of the private sector over the pre-crisis years.

Tables 5a and 5b: Solution for the year 2008

4 What happened between 2008 and 2019

In this section, departing from the 2008 solution, we feed the model with the time paths of policy variables and the index of property rights as they are in the data. In doing so, we assume that after 2019 the values of these variables remain unchanged as in 2019 which is the last value available in the data as this paper is written. In what follows, we will report both aggregate and distributional implications. Recall that this is without taking into account the covid-19 shock that hit the Greek economy in 2020 (this will be studied in section 6).

4.1 Aggregate effects

Our baseline simulation for GDP, as well as its actual path in the data, are illustrated in Graph 1, where the numbers indicate the percentage change in output relative to the 2008 solution. As can be seen, our model solution can mimic relatively well the actual behaviour of GDP over the crisis years, especially its cumulative change. For example, between 2008 and 2016, the total output loss generated by the model is 22.7% (namely, $100 - 77.3 = 22.7$), while it was 26.2% (namely, $100 - 73.8 = 26.2$) in the actual data. On the other hand, it should be acknowledged that the model fails, for example, to generate the economic downturn in 2013 and the relative recovery after 2016; this is not surprising since here we have deliberately focused on two exogenous factors only (the policy package and institutional quality) leaving aside a lot of other economic and political factors that were happening at the same time. Given this, we feel that the model is empirically plausible and can allow us to draw some useful policy implications.

Graph 1: Output loss and the data

In Graph 2, we decompose the simulated output loss into its main drivers. As the graph reveals, about 13% of the loss is due to the economic ajustment package adopted (where the latter includes fiscal austerity, structural reforms and the various forms of international financial assistance). Another 9.8% (specifically, $87.1 - 77.3$) is due to the deterioration of institutional quality since 2008. The role of the latter is striking.

Graph 2: Output loss and its main drivers

4.2 Distributional effects

Our solution also allows us to quantify the distributional implications of the aggregate output loss during the debt crisis year. Recall that we have three distinct income groups in the model, entrepreneurs, private workers and public employees, as modeled in subsection 2.2 above. Graph 3 depicts respectively the simulated time paths of the worker's to entrepreneur's net income ratio and of the public employee's to entrepreneur's net income ratio over the debt crisis years 2008-2019 (net incomes are defined in Appendix A.7 of the supplementary file). These paths follow by using the model's solution into the budget constraints of the three types of households in subsection 2.2.

Graph 3: Distributional effects

Inspection of Graph 3 reveals that, after an improvement at the start of the crisis, the net income gap between workers and entrepreneurs became wider. The same applies to the net income gap between public sector employees and entrepreneurs. Putting them together, these two graphs imply that inequality has worsened, although the big losers from the debt crisis have been the private workers. Their net income has suffered more than that of public employees and, although it has somehow managed to recover after a sharp fall in the early years of the crisis, their share remains below that in the pre-crisis years.

Although we do not have access to actual data so as to compare them to our simulated paths, we believe our results are in line with the widespread belief that the global financial crisis, as well as the policy mix chosen to deal with its effects, has mainly hurt those who are unskilled and work in the private sector (see e.g. Bourguignon (2018) for evidence across several countries and Andriopoulou et al. (2018) specifically for the Greek economy).

5 Counterfactuals between 2008 and 2019

In this section, we conduct two types of experiments. First, we consider what would have happened since 2008 without international financial aid. Second, we study what would have happened since 2008 if, given aid, some things had been done a bit better. Recall again that this is without taking into account the covid-19 shock that hit the Greek economy in 2020 (this will be studied in section 6).

5.1 Counterfactuals: It could have been much worse

We first switch off fiscal aid. This is to examine what would have happened if EU states and institutions had not stepped in to repay debt obligations and to purchase the Greek sovereign debt when the country was shut out of the bond market and trust was lost. Say, for example, that the Greek government would have to increase income taxes, τ^{y}, to make up for the loss in public revenue due to setting $\lambda^{eu} \equiv 0$. This experiment is shown in Graph 4. As can be seen, in this case, the depression would be much deeper and, most probably, would have triggered a severe social unrest.

Graph 4: Counterfactual: No fiscal bailout

We have also attempted to switch off *TARGET2* balances, which, as we have seen, has been the main form of monetary policy aid from the ECB to Greece. This is to examine what would have happened if the ES, via the Greek NCB, had not followed an accommodative monetary policy towards Greece. In this case, we report that our model does not exhibit dynamic stability.[49] In simple words, we cannot get a solution. This - according to our view - confirms the important role played by the ECB in the Greek bailout.

[49] When we set the change in *TARGET2* liabilities exogenously (in this particular counterfactual, equal to zero) another fiscal, or balance-sheet monetary, policy variable has to take its place in the category of endogenous variables. We have experimented with various possibilities. None of them delivers a stable solution over this period.

5.2 Counterfactuals: It could have been much better

In this subsection, we restore financial (fiscal and monetary) aid, as in the baseline simulations of section 4, and examine what would have happened if some things had been done slightly better.

Graphs 5 and 6 illustrate respectively the simulated paths of GDP when we assume lower income tax rates and higher public spending other things equal. That is, in these graphs, there is a milder fiscal austerity. In particular, in Graph 5, we have arbitrarily set the income tax rates 2 percentage points (pp) lower than in the data in each year, while, in Graph 6, we have arbitrarily assumed that each item of public spending, as share of GDP, is 2 pp higher than in the data in each year. Notice that we change one thing at a time. As can be seen, the output loss would be milder, although the gains are small. Also note that, in these cases, the cut in taxes, or the rise in spending, are like free lunches because any fiscal expansion has been assumed to be accommodated by a rise in *TARGET2* liabilities which continue to adjust residually. By contrast, in Graph 7, we assume a "budget neutral" fiscal policy mix, in the sense that income tax rates are cut by 2 pp (or public investment, as share of GDP, rises by 2 pp), but, at the same time, transfers as share of GDP are also cut by 2 pp. In this more realistic fiscal scenario, again the output loss would be milder but not by much. In Graph 8, we assume a stronger liberalization in product markets. In particular, we assume that the Dixit-Stiglitz parameter of product substitutability gets closer to its value in the core countries of the EZ (from 0.775 to 0.80); these numbers are similar to those used by Eggertsson et al (2014). Again there is a milder depression but again we cannot see spectacular improvements. Finally, in Graph 9, we combine the scenaria of Graphs 7 and 8, and, more importantly, we now set the index of property rights as it it was in the Greek data before the crisis (specifically, we keep PR_t constant at its 2009 value for ever).[50] In this case, the output loss would be only 9.9% (namely, $100 - 90.1 = 9.9$), which is close to that experienced by other EZ periphery countries hit by the global financial crisis. This confirms, once more, the key detrimental role played by institutional deterioration during the Greek

[50] The deterioration of institutional quality in the period 2008-2016, which is clearly seen in the data, is characterized by two main milestones. The first concerns the violent demonstrations, accompanied by extensive destruction of private property, in the center of Athens, in December 2008. The second concerns the political polarization and lack of political consensus since 2010, which was the year of the first memorandum of understanding offering financial assistance in exchange of fiscal austerity and structural reforms (the so called economic adjustment program). All these developments, fuelled by political commentators, led to strikes, protests and even terrorist attacks, which further deteriorated institutional quality and undermined economic confidence and sentiments. In the scenario, in which we investigate what would have happened if the quality of institutions had not been deteriorated, we assume that institutional quality remains at its 2009 value and not at its 2008 one, because the events of 2008 preceded the economic adjustment program and its implications.

depression.

Graph 5: Counterfactual: Less fiscal austerity - lower taxes
Graph 6: Counterfactual: Less fiscal austerity - higher spending
Graph 7: Counterfactual: Alternative fiscal mixes
Graph 8: Counterfactual: Stronger product market liberalization
Graph 9: Putting counterfactuals together

6 The new covid-19 crisis and policies from now on

In the beginning of 2020, the world was stricken by the covid-19 pandemic which, at the time of this writing, is expected to cause a severe economic downturn worldwide. A public finance crisis is also expected to follow as most governments have stepped in and new "unprecedented" fiscal and monetary policies have been adopted or promised to be adopted. Greece is not an exception. Actually, the pandemic struck the Greek economy when it was on a moderate growth path after years of depression as analysed above. Also, the pandemic finds Greece with limited fiscal space (its public debt was already around 175% of GDP in the end of 2019).

This raises (at least) two interrelated questions: First, what will be the depth and the length (i.e. the size and the duration) of the economic downturn? Second, what are the right policy reactions to the new economic crisis? As is widely recognized (see e.g. European Commission (2020a)), although the shock is symmetric hurting most countries, its effects will be uneven depending, except from the severity of the pandemic and the stringency of the containment measures in each country, on how the shock propagates to each economy, the initial conditions and the way each country responds to the economic downturn. In this section, using our macroeconomic model for Greece and the lessons from the debt crisis in 2008-2016, we will try to give quantitative answers to these questions.

6.1 An informal description of model changes

Although there are many ways in which the pandemic can trigger an economy crisis, here, following most of the related literature (see e.g. Eichenbaum et al (2020)), we assume that the drop of economic activity is triggered by an adverse labor supply shock. This is because the impact effect of the covid-19 shock has been mainly on employment; this has happened through compulsory lockdown but also through absenteeism, sickness and precautionary behavior as people have reacted to the health risk by reducing their labor supply. Therefore, following Eichenbaum et al (2020), we assume that households' labor supply is restricted in the sense that they can supply only a fraction $0 < \Phi_t \leq 1$ of the labor supply that they would had supplied in the absence of the pandemic other things equal.[51] This restriction on the labor supply is translated into a corresponding cut in labor income (except from the labor income of public employees which we assume to remain uncut).[52] As in Eichenbaum et al (2020), at least in our baseline scenario below, we will set Φ_t at 0.8 in 2020 and 1 afterwards meaning back to Greek normality in 2021 onwards. As we shall see, even this relatively mild shock, propagated via the various demand and supply channels of our macroeconomic model, can lead to a severe economy-wide downturn accompanied by a sharp deterioration in public finances.

In addition to the Φ_t shock and its impact effect on labour supply, the only thing that changes (relative to the model used so far for the study of the Greek debt crisis) is the treatment of public debt. Since Greece exited its economic adjustment program in August 2018, which among other things means that nowadays the Greek government borrows from the market rather than from European public institutions, we assume that public debt is the public financing variable that adjusts to close the budget identity of the consolidated government sector. Recall that, by contrast, during the period of the economic adjustment program in 2010-2018, we assumed that it was *TARGET2* liabilities that played this role with the public debt to GDP ratio set as in the data.[53] All other policy variables, national or supranational, are assumed to remain constant at their 2019 values.

Modelling details are provided in Appendix D of the supplementary file.

6.2 How we work and policy scenaria

We now discuss how we work and the main policy scenaria studied. As in the study of the debt crisis above, we work in steps.

First, employing the model used so far, we get a stationary solution using data of the year 2019. This solution will serve as a departure point for our new numerical simulations. Second, departing from this solution, we will

[51] We report that we have experimented with additional shocks and distortive effects from covid-19, like restrictions on firms' sales, ad hoc cuts in consumption, etc. The economic damage becomes worse. We use a labor supply shock only because, as we shall see, it is enough, on its own, to generate a recession of similar magnitude to that discussed by international institutions (see e.g. European Commission (2020a, 2020b)).

[52] In all scenaria studied, we assume that there is an extra lump-sum transfer to public sector employees denoted as $g^{cov}_{b,t}$, that insulates their labor income from the pandemic. That is, even if they are forced to work less like all other househodls, they are compensated by a transfer, $g^{cov}_{b,t} = (1-\tau^y_t)w^g_t(1-\Phi_t)l_{b,t}$. Details are in Appendix D.

[53] That is, public debt and *TARGET2* balances change places. The latter was an endogenous public financing variable during 2010-2018 (see above), while, after the exit from the economic adjustment program, and as assumed traditionally, this role is now played by the end-of-period public debt, while, the exogenously set *TARGET2* liabilities are assumed to follow an autoregressive and state-contingent rule which means that they fluctuate around their 2019 value. Note that state-contingency of *TARGET2* liabilities to the public debt gap is necessary for dynamic stability. Details are in Appendix D.

modify the model as explained in the previous subsection (namely, we add the labor supply shock, Φ_t, and switch public debt to the list of endogenous variables) keeping all other driving forces (exogenous and policy variables) at their 2019 values. This will enable us to get a measure of the economic effects of the pandemic other things equal. As said, we will start by setting Φ_t at 0.8 during 2020 and at 1 from 2021 onwards. We label this to be our bad scenario regarding the impact of covid-19 without any government policy reaction. Finally, as we did in our study of the debt crisis, we will study alternative policy reactions to the pandemic crisis focusing on the following scenaria: (I) The government, during 2020, makes a lump-sum transfer to all households, and not only to public employees which was the case assumed in the bad and the worse scenaria above. This transfer covers the reduction in all labor incomes caused by the pandemic shock.[54] (II) On top of (I), during 2020 and 2021, the government also increases temporarily by 1 percentage point all public spending items as shares to GDP apart from public wages (the latter have remained uncut through the assumed transfer). (III) On top of (I)-(II), from 2020 ownwards, the government also reduces permanently the effective income and consumption tax rates, each by one percentage point, and this extra loss in public revenue is somehow balanced by cuts in government transfers by the same percentage point from 2021 ownwards.

Before proceeding, it is worth saying the following. We believe that, among all the above mentioned scenaria, the possible quantitative impact of covid-19 on the Greek economy can be better captured by scenario (III), since the Greek government has already adopted, or has promised to adopt, a set of policy measures which include, among others, transfers to households and firms, increases in public spending in general and tax reductions or discounts. Scenaria (I) and (II) however can help us to understand the effect of one policy measure at a time.

Help from the EU In addition to the above responses, as this paper is written, discussions take place at EU level about the establishment of a new fund, the so-called European Recovery Fund, whose aim will be to raise money from private markets and then allocate it to member-countries depending on how much they have been hurt by the covid-19 pandemic (see European Commission (2020b)). Although the relevant negotiations seem to be still at an early stage, according to the information available so far, Greece could benefit up to a net amount of 32 billion euros mainly in the form of grants, if this plan is finally implemented. This amount translates into around 17% of the Greek GDP in 2019, and should be used by the

[54] That is, similarly to public sector employees, we now add extra lump-sum transfers to the income groups working in the private sector, denoted as $g^{cov}_{k,t}$ and $g^{cov}_{w,t}$ that compensate their members for the loss of labor income due to the pandemic. That is, in equilibrium, $g^{cov}_{k,t} = (1-\tau^y_t)w^k_t(1-\Phi_t)l_{k,t}$ and $g^{cov}_{w,t} = (1-\tau^y_t)w^w_t(1-\Phi_t)l_{w,t}$. Details are in Appendix D.

end of 2024. As is obvious, given that a big recession, at least in 2020, is considered to be rather unavoidable, the efficient use of this "manna from heaven" money is absolutely crucial, not only as a means of reducing the 2020 output loss, but mainly as a tool of restructuring the Greek economy in the years to come.

Therefore, in an attempt to quantify the effects of this new financial assistance from the EU, in addition to scenaria (I)-(III), which had to do with policy reactions at national level, we will also investigate the following three scenaria all of which incorporate this EU assistance to our model:[55] In scenario (IV), on top of the policy measures included in scenario (III), which will serve as the benchmark, we assume that the Greek government uses the 32 extra billion euros from the EU to finance public investment, $g^i_{g,t}$, over the years 2021-2014 (we assume that one fourth of the total amount is used for this purpose each year). This can give us an idea of the potential benefits from the the EU support when the country makes a "good" use of the money received. In scenario (V), on top of (IV), we assume that the country also implements stronger - and at a faster pace - reforms in the product market so as the degree of competition in the Greek product market approaches the one in the core eurozone countries within three years. In particular, we assume that the Dixit-Stiglitz parameter of product substitutability increases gradually from 0.775 to 0.80. This attempts to capture the contribution of structural reforms, here in the form of stronger product market liberalization, to economic recovery. Finally, in scenario (VI), we go to the other extreme from (IV) and (V). Now, instead of assuming that Greece uses the amount of 32 billion euros to finance public investment, we assume that this amount is misused in the sense that it becomes a contestable prize and that atomistic economic agents compete with each other for a share of this contestable prize. We do so because there is a lot of anecdotal, as well as econometric, evidence that, in countries with weak institutions, like Greece, foreign aid transfers increase the size of the prize that interest groups fight over and hence induce rent seeking activities (see Drazen (2000, chapter 12) for a review of this literature, while see e.g. Economides et al (2008) for empirical evidence on the impact of international aid). In turn, rent seeking in the recipient country, and the distortion of incentives triggered by this type of anti-social competition, mitigate the beneficial effects that foreign aid may have in the first place. Our model of Tullock-type rent seeking competition, as developed in section 2.1 above, can easily accommodate this possibility; we just have to add the amount of 32 billion euros (one fourth of it in each year from 2021 to 2024) to the contestable prize that already exists (see equations (3b), (7b) and (10b) and the associated first-order conditions

[55] In terms of modeling, we just have to add the assumed amount of financial assistance, or foreign aid, to the budget constraint of the government and of course to the balance of payments.

for rent seeking time).

6.3 Main findings

Departing from 2019, Graph 10 illustrates the simulated path of GDP when the economy is hit by the covid-19 shock in 2020 as defined above and if there is no policy reaction at all. In the so-called bad scenario, as said above, Φ_t takes the value of 0.8 in 2020 and then returns to 1 for ever. In this graph, we also study a worse scenario in which Φ_t takes the value of 0.75 in 2020, which can be thought of as the case in which there is a second wave of the pandemic which might require a new lockdown of households/firms (however, even in this worse scenario, Φ_t is assumed to return to 1 in 2021 and to remain there for ever). As can be seen in Graph 10, in the bad scenario, the economy loses almost 12% of its output relatively to 2019, whereas, in the worse scenario, this loss exceeds 15%. To make it worse, the economy does not manage to rebound in the years after in the sense that GDP remains below its 2019 level. These results show the big vulnerability of the Greek economy to supply shocks even of relatively small magnitude. They also imply that government intervention has been more than necessary.

Graph 10: The economic impact of covid-19 without any response

Graph 11 presents the simulated paths of public debt to GDP under the bad and the worse scenaria. In the bad scenario, the public debt to GDP ratio in 2020 exceeds 225%, whereas, in the worse scenario, it jumps to 247%. However, as said, all this is without policy reaction, which once implemented, is expected to limit the economic downturn and the rise in public debt. We now turn to policy reactions.

Graph 11: The public debt to GDP ratio without any response

In Graph 12, we investigate whether the various policy measures and/or reforms, defined as scenaria (I), (II) and (III) above, can mitigate the economic damage from covid-19. In particular, compensating all income groups for the labor income losses they have suffered (this is scenario I) results in an output loss of about 11% in 2020, whereas, in 2021, the output is expected to grow at a rate of about 9.9%. However, the economy cannot make up for its output losses in the years after. If, on top of compensating all income groups for their labor income losses, the government also increases temporarily (for the years 2020 and 2021) all government spending items by 1 percentage point (this is scenario II), the recession in 2020 gets milder amounting to a drop of about 8.8% instead of 11% which was the case under scenario I. On the other hand, again, although the economy is expected to grow at a rate of about 8.7% in 2021, its GDP cannot return to its 2019 level in the coming years. Putting these results together, reacting with public spending instruments only can produce an incomplete and gradual (U-shaped) recovery only. If, however, increases in government spending are accompanied by permanent decreases of 1 percentage point in effective income and consumption tax rates, which are financed by equal cuts in government transfers from 2021 ownwards (this is scenario III), then aggregate things get relatively better. In this case, the GDP loss in 2020 is limited to 8.6% and the economy is expected to grow at a rate of about 9.4% in 2021 restoring fully, even in absolute terms, its output capacity. Thus, the tax-spending mix will be crucial to the recovery, as it was the case during the previous, debt crisis.

Graph 12: The economic impact of covid-19 under scenaria (I), (II) and (III)

Graph 13 presents the simulated paths of public debt to GDP under scenaria (I), (II) and (III). For example, the adoption of policy measures, such as the ones described in scenario (III), can limit the increase of public debt to GDP ratio to about 213.7%, relative to about 225% in the bad scenario discussed above, despite the increased fiscal cost associated with the expansionary government measures; this is thanks to the lower output loss that this scenario implies. In all cases, however, the public debt to output ratio deescalates after the impact year as the economy rebounds, athough at different paces depending on the scenario assumed.

Graph 13: The public debt to GDP ratio under scenaria (I), (II) and (III)

Next, Graph 14 presents the simulated paths of output under scenaria (IV), (V) and (VI) as defined above. In particular, under scenario (IV), the output loss in 2020 is limited to about 6.5%; recall that, according to this scenario, the Greek government has at its disposal extra 32 billion euros from the EU all of which are assumed to be used to finance public investment plans allocated equally over the years 2021-2024. Moreover, in this scenario, in all years after 2020, the GDP is well above its pre-crisis 2019 level. In turn, if the spending and tax policy measures, included in scenario (IV), are complemented by the implementation of stronger product market reforms so as the associated degree of competition approaches that in the core eurozone countries (this is scenario V), the output loss is limited to 5.6% in 2020. and the economy enjoys even stronger growth in the years after. Finally, the black line in Graph 13, illustrates the path of GDP under scenario (VI) which is the "misuse" scenario. Now, as defined above, the 32 billion package plays the role of a common pool attacked by rent seekers. This scenario, in addition to a huge waste of resources, condemns the country to economic stagnation and, in terms of GDP, it is as if the country has received no international aid (the time path of GDP under VI coincides with that under III).

Graph 14: The economic impact of covid-19 under scenaria (IV), (V) and (VI)

Finally, Graph 15 presents the simulated paths of public debt to GDP under scenaria (IV), (V) and (VI). In scenario (IV), the public debt to GDP ratio in 2020 approaches 207%, whereas, in scenario (V), the same ratio reaches 204%. In 2024, the public debt to output ratio falls to 168.5% under (IV) and 166.6% under (V) respectively. In other words, economic growth helps the country to grow out its public debt. By contrast, under the misuse scenario (VI), public debt jumps to 212.3% and remains high in the coming years.

Graph 15: The public debt to GDP ratio under scenaria (IV), (V) and (VI)

The above results confirm the main message of the paper even in the case of the new covid-19 crisis. In particular, a different spending-tax policy mix, product market liberalizatiom and, above all, a socially productive use of the available resources, can help the Greek economy, not only to overcome the pandemic with the minimum possible output losses in 2020, but also to achieve higher medium-term economic growth and a lower public debt-to-GDP ratio over time.

7 Closing remarks, caveats and extensions

In this paper, we have provided a detailed anatomy of the Greek sovereign debt crisis by using a medium-scale micro-founded macroeconomic model that incorporated the key features of the Greek economy. The focus was, not only on the role of fiscal austerity, but also on the roles of international aid and institutional quality both of which have been closely associated with fiscal austerity. We finally analysed the recent covid-19 pandemic crisis.

Since the main results have already been stated in the Introduction, we close with a discussion of some key assumptions, caveats of the model and possible extensions. Here, we modeled, and also measured, institutional quality in a specific way. We assumed that firms can keep a fraction of their output only, with the rest being taken away by rent-seekers, where this fraction was set according to an index measuring the enforcement of property rights. This index, as already said, reflects both hard data on core institutional fundamentals (the rule of law, regulatory quality, violence and political stability, etc) and perceptions (where the latter were, most probably, also influenced by the fear of sovereign default or the so-called fear of Grexit). An extension could be to model, and measure, separately the effects of the country risk (expectations of exit from the Eurozone as in e.g. Kriwoluzky et al. (2019) or model uncertainty and worst-case scenaria as in Hansen and Sargent (2008)) and the effects of changes in core institutional fundamentals. Ideally, one should endogenize both of them; see e.g. Corsetti et al. (2013) for a model of the ex ante sovereign default probability, while see e.g. Besley and Persson (2009) for a model of endogenous institutional quality, where the latter is shaped by current choices as well as by past investments in state capacity. Another interesting extension could be to add a core creditor country like Germany, so as to have a closed general equibrium system of the EZ. This would enable us to examine how financial aid given to one country affects the other country and, in particular, how the various fiscal and monetary bailouts provided to Greece have affected the core of the EZ (see e.g. Philippopoulos et al. (2017b) for a related two-region model). We leave these extensions for future work.

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Tables, figures and graphs

Table 1
Baseline parameterization

Parameter	Description	Value
ν	home goods bias in consumption	0.5
μ_1	weight of consumption in utility	0.4
μ_2	weight of leisure in utility	0.55
μ_3	weight of money balances in utility	0.03
β	savers' time discount factor	0.99
β_k	borrowers' time discount factor	0.98
δ	depreciation rate of private capital	0.05
δ^g	depreciation rate of public capital	0.05
ψ^p	transaction cost in foreign capital market (private)	0.5
ψ^g	transaction cost in foreign capital market (public)	0.5
A^p	TFP in private sector's production function	1
A^g	TFP in public sector's production function	1
A^k	entrepreneurs' labour productivity	3
A^w	workers' labour productivity	2
$1-\alpha$	share of labor in private production	0.6
σ	contribution of public output to private production	0.1
θ_1	share of capital and imported goods in public production	0.3045
θ_2	share of labor in public production	0.6
χ^p	intensity of private capital relative to imported goods (private)	0.5
op	substitutability between capital and imported goods (private)	0.5
χ^g	intensity of public capital relative to imported goods (public)	0.5
og	substitutability between capital and imported goods (public)	0.5
ξ^k	capital adjustment cost parameter	0.3
ξ^l	transaction cost associated with bank loans to firms	0.3
ξ^z	transaction cost associated with NCB loans to banks	0.3
ξ^b	transaction cost associated with bonds held by banks	0
γ	measure of diminishing returns in anti-social activities	0.5
ψ^*	country's interest-rate premium parameter	0.05

Table 1 continued
Baseline parameterization

Parameter	Description	Value
$\overline{d}$	threshold value of public debt to ouput	1.1
Γ^k	efficiency of entrepreneurs' anti-social activity	1
Γ^w	efficiency of workers' anti-social activity	0.7
Γ^b	efficiency of public employees' anti-social activity	1.3
Θ	constant in the function of exports	0.5
ϑ	Cobb-Douglas exponent in the function of exports	2
$\overline{f}$	threshold value of external debt to output	0.8
i^*	constant term of world interest rate	0.01
θ	substitutability between intermediate goods	0.75
ξ^p	price adjustment cost parameter (Rotemberg)	3
ρ^l	fraction in firms' borrowing constraint	0.5
ρ^z	fraction in banks' borrowing constraint	0.5
n^k	share of capitalists in population	0.2
n^w	share of workers in population	0.6
n^b	share of public employees in population (data)	0.2

Table 2
Greek public debt to GDP and its main holders

Year	Total public debt (% of GDP)	λ^{eu} (% of total public debt)	λ^g (% of total public debt)
2008	109.4	0	75
2009	126.7	0	75
2010	146.2	9.3	46.3
2011	172.1	19.9	24.7
2012	159.6	59.9	20.3
2013	177.4	66.3	18.2
2014	178.9	67.2	16.9
2015	175.9	68.6	16.1
2016	178.5	69.8	16.0
2017	176.2	70.9	16.0
2018	181.2	70.9	16.0
2019	176.7	70.9	16.0

Source: Public Debt Management Agency and Greek Ministry of Finance.

Table 3a
Bank of Greece's assets
(billions of euros, end of year)

Year	Lending to banks	Securities	Government long-term debt	Total assets
2007	9	10	8	42
2008	38	14	8	71
2009	50	21	7	86
2010	98	24	7	13
2011	128	21	7	168
2012	121	21	6	160
2013	73	21	6	109
2014	56	31	5	103
2015	107	40	5	163
2016	67	57	6	142
2017	34	74	6	125
2018	11	76	5	109
2019	8	75	5	109

Source: Bank of Greece.

Table 3b
Bank of Greece's liabilities
(billions of euros, end of year)

Year	Banknotes	TARGET2	Reserves	Government deposits	Total liabilities
2007	16	10	7	1	42
2008	18	35	8	1	71
2009	21	49	8	1	86
2010	22	87	10	2	138
2011	23	105	5	5	168
2012	23	98	2	7	160
2013	25	51	2	8	109
2014	27	49	3	5	103
2015	29	94	1	5	163
2016	30	72	1	9	142
2017	31	59	2	12	125
2018	33	29	7	25	109
2019	30	26	9	27	109

Source: Bank of Greece.

Table 4a
Government revenue and expenditure

Variable (% of GDP)	2008	2010	2011	2014	2016	2018	2019
Revenue	40	41	44	47	49	48	47
Expenditure	50	53	54	51	49	48	46

Source: European Commission (Report on Public Finances in EMU).

Table 4b
Fiscal (spending-tax) policy variables

Variable	s^g	s^w	s^i	s^{tr}	τ^y	τ^c
Year	(% GDP)	(% GDP)	(% GDP)	(% GDP)	(effect.)	(effect.)
2008	9.1	11.6	5.8	18.9	27.3	16.8
2009	10.2	13.1	5.7	20.6	27.1	15.2
2010	9.8	12.4	3.7	20.9	27.6	17.6
2011	9.1	12.6	2.5	22.9	29.8	19.0
2012	9.0	12.8	2.5	23.2	33.6	18.5
2013	8.4	12.1	3.4	21.4	32.3	18.7
2014	8.2	12.2	3.7	21.8	33.4	19.1
2015	8.2	12.1	3.8	22.0	34.4	19.4
2016	8.1	12.1	3.5	22.1	35.	21.5
2017	8.2	11.9	4.4	21.3	36.0	21.3
2018	7.3	11.8	3.0	20.7	35.4	22.5
2019	7.7	11.7	2.2	20.7	NA	NA

Source: Eurostat and own calculations.

Table 5a
Main variables in the solution for the year 2008

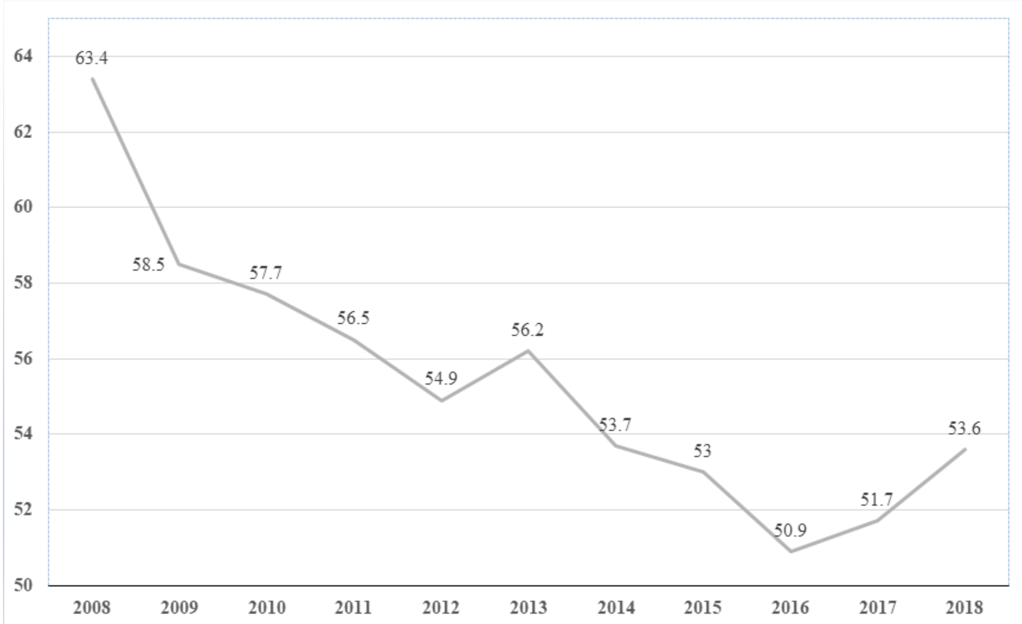
Variable	Description	Model solution	Data
c/y	Consumption to ouput	85.6%	67.4%
inv/y	Investment to output	19%	23.8%
f/y	Foreign debt to output	82.1%	76%

Source: Eurostat.

Table 5b
Other variables in the solution for the year 2008

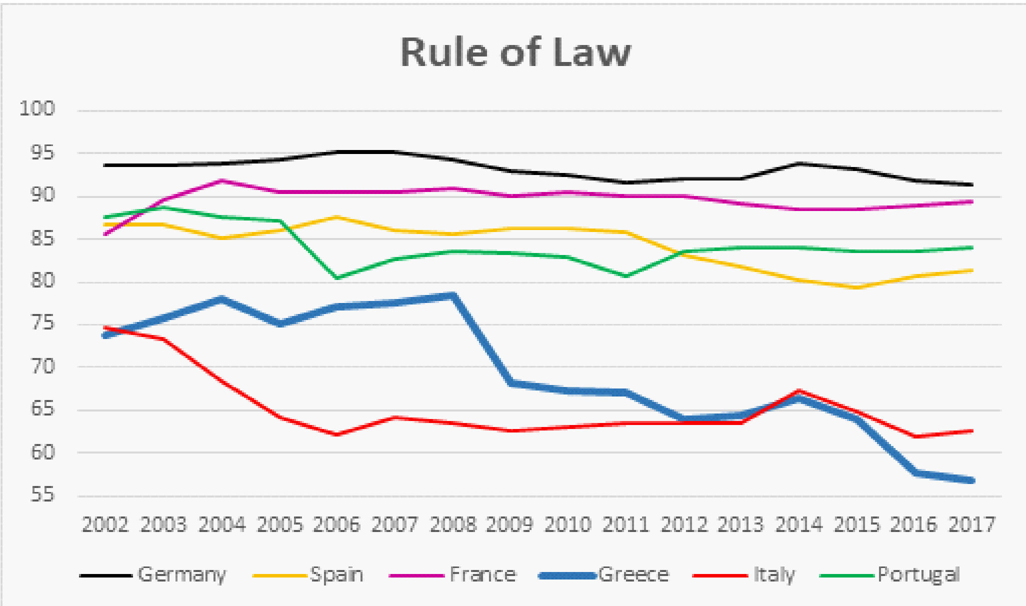
Variable	Descritpion	Value
c_k	consumption of entrepreneur	0.306
c_w	consumption of private worker	0.16
c_b	consumption of public employee	0.253
l_k	work hours of entrepreneur	0.02
l_w	work hours of private worker	0.20
l_b	work hours of public employee	0.175
TT	terms of trade	0.31
y	per capita real output	0.243
s_k	capitalist's effort time allocated to anti-social activities	0.085
s_w	worker's effort time allocated to anti-social activities	0.093
s_b	public employee's effort time allocated to anti-social activities	0.126

Figure 1a
Property rights in Greece



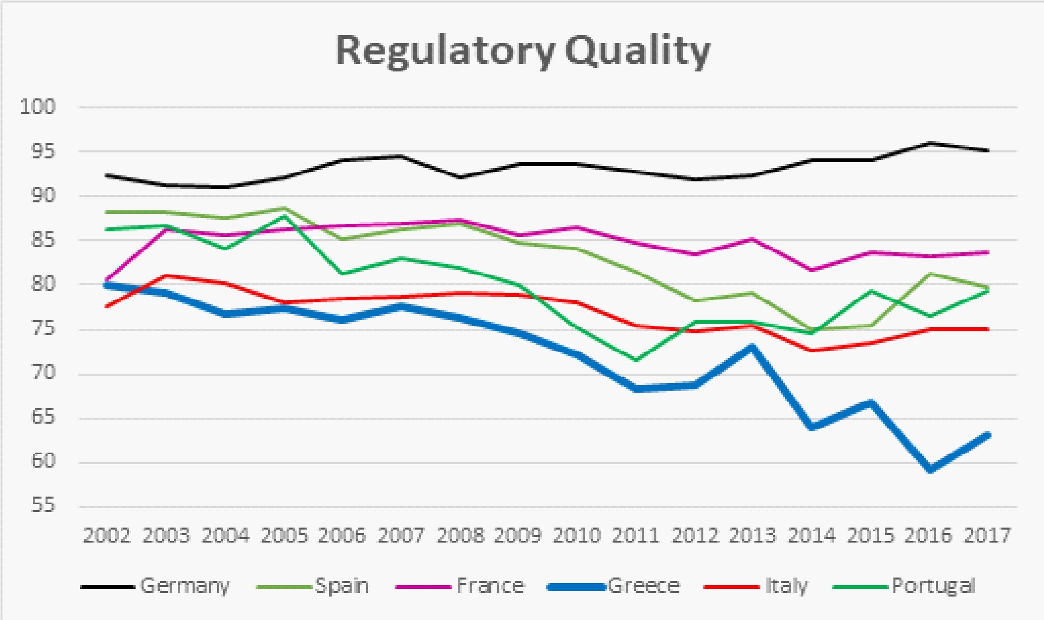
Source: World Governance Indicators.

Figure 1b
Rule of law, comparison to other countries



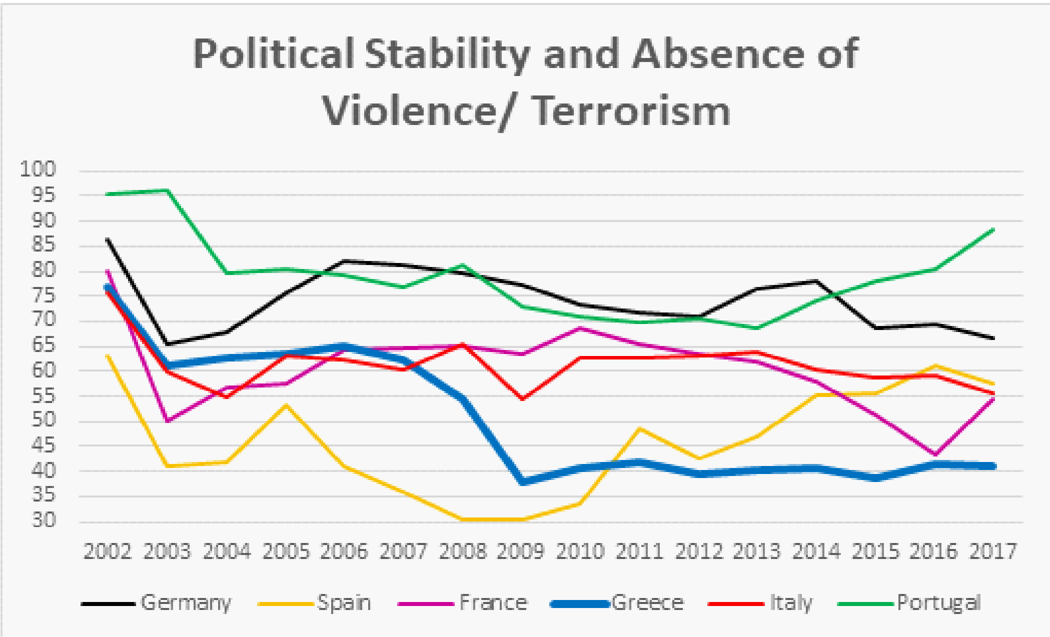
Source: World Governance Indicators.

Figure 1c
Regulatory quality, comparison to other countries



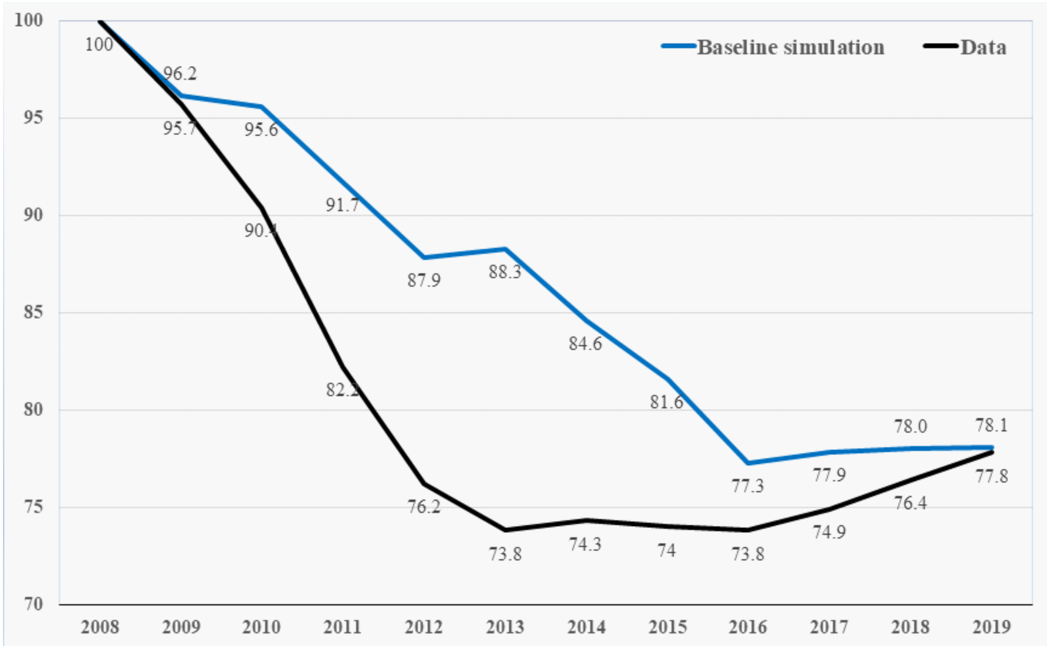
Source: World Governance Indicators.

Figure 1d
Political stability and absence of violence/terrorism, comparison to other countries



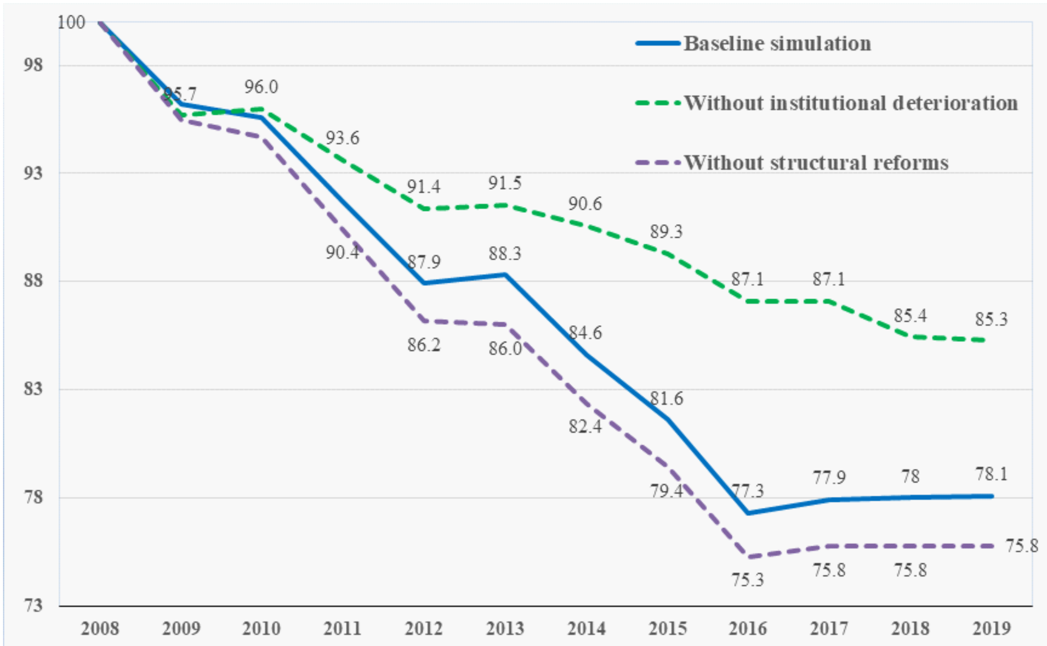
Source: World Governance Indicators.

Graph 1
Output loss and data

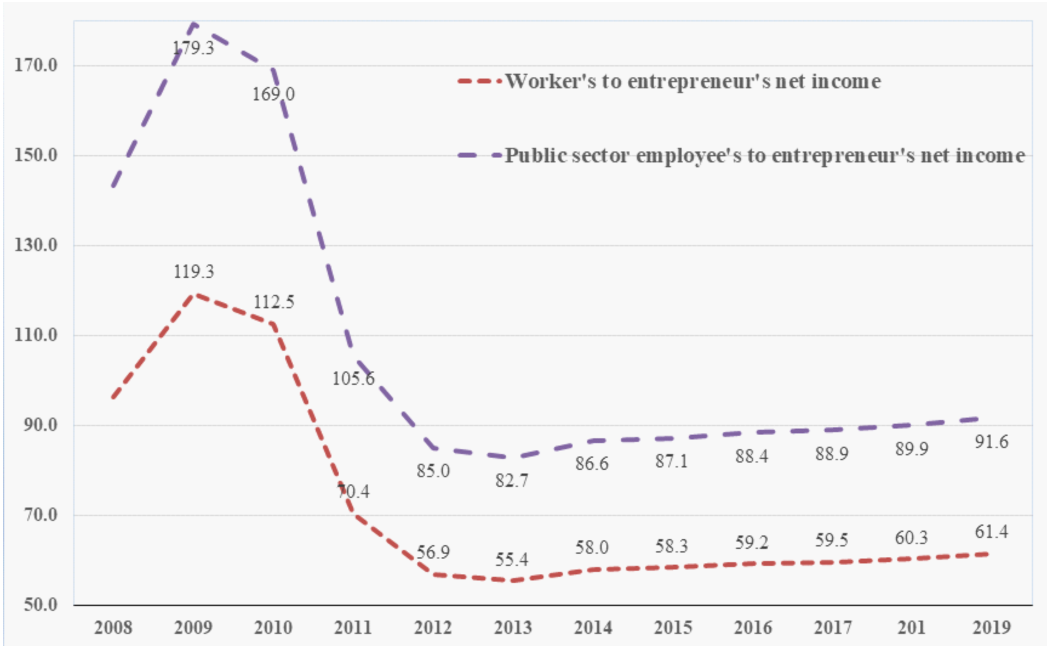


Source: Eurostat.

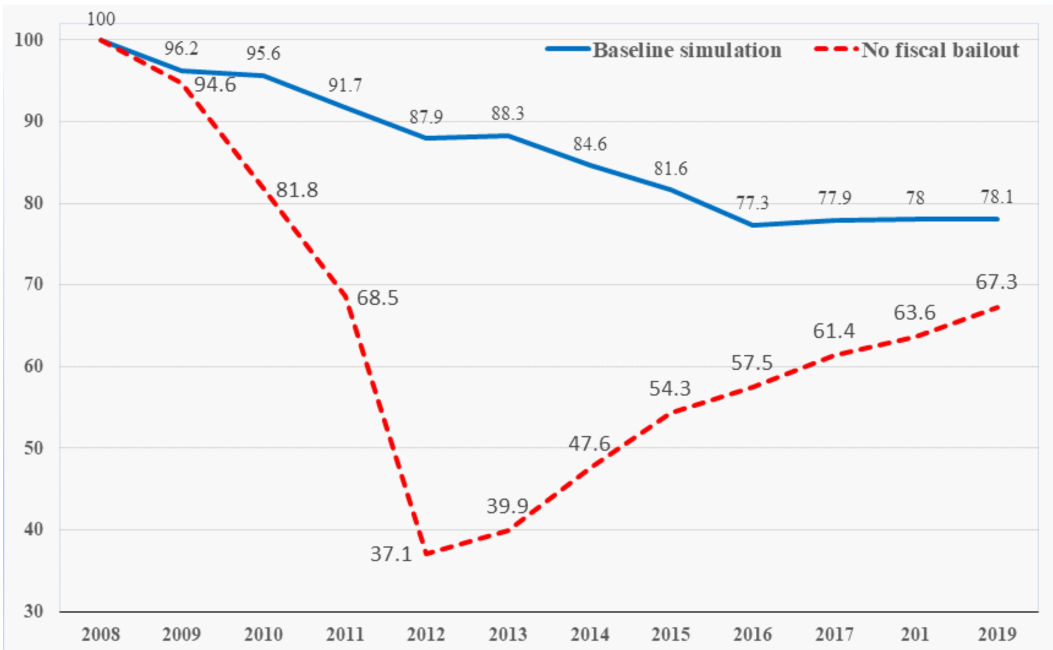
Graph 2
Output loss and its main drivers



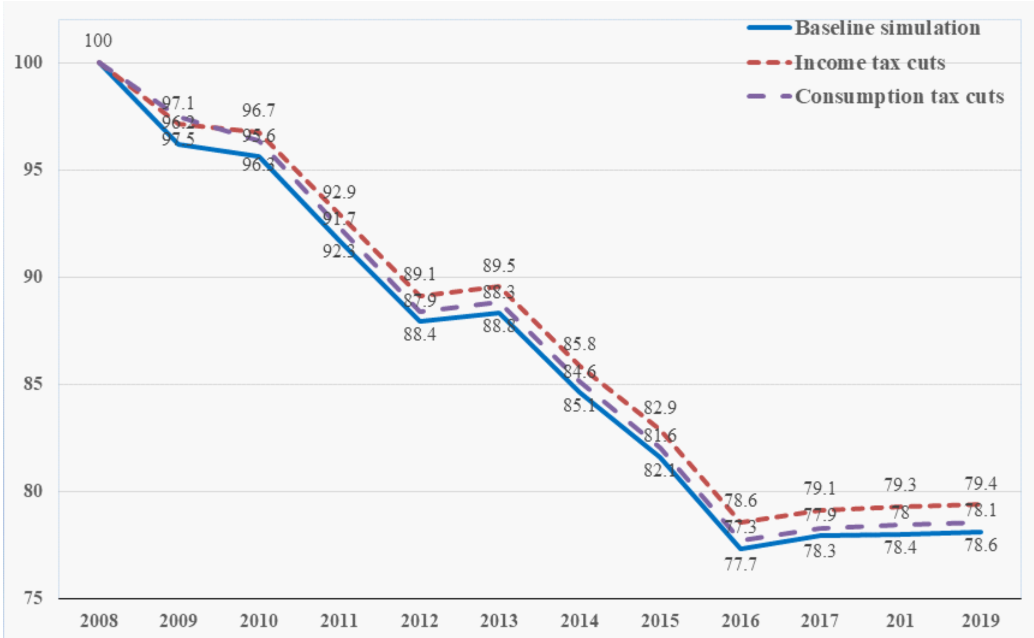
Graph 3
Distributional effects



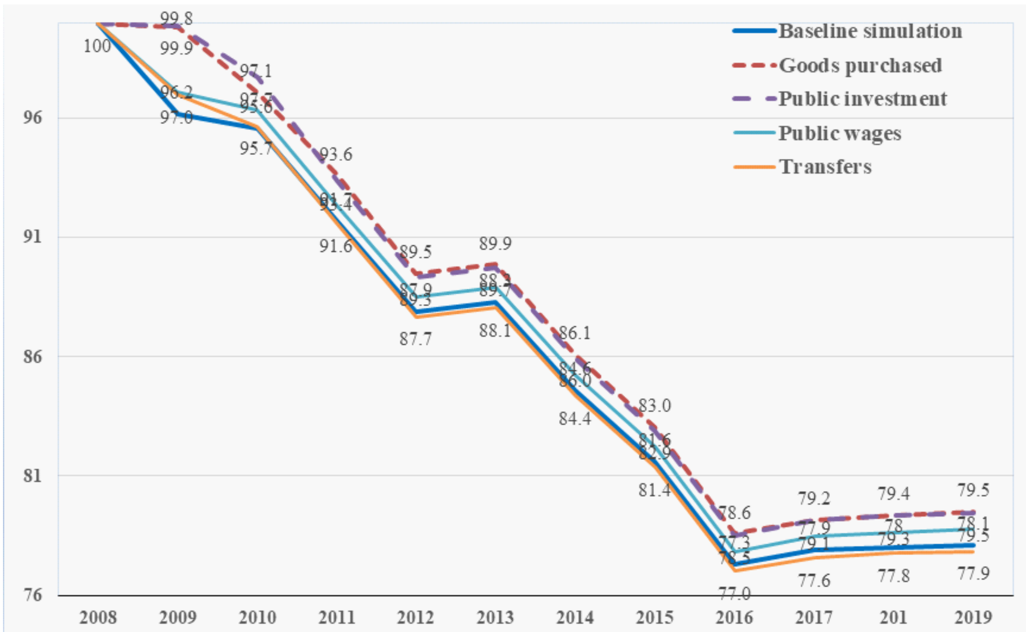
Graph 4
No fiscal bailout



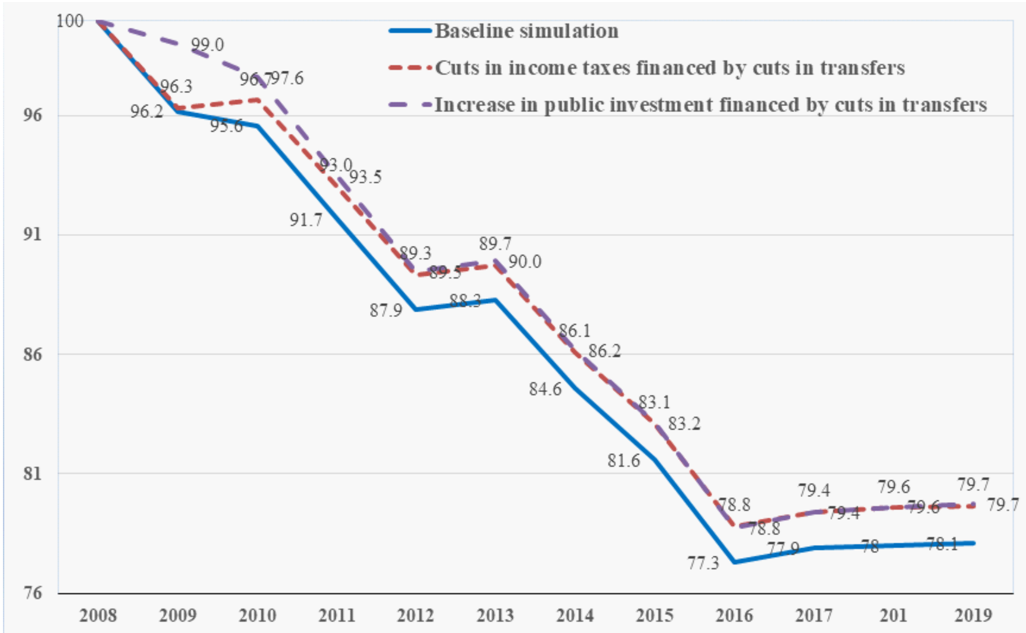
Graph 5
Less fiscal austerity - lower taxes



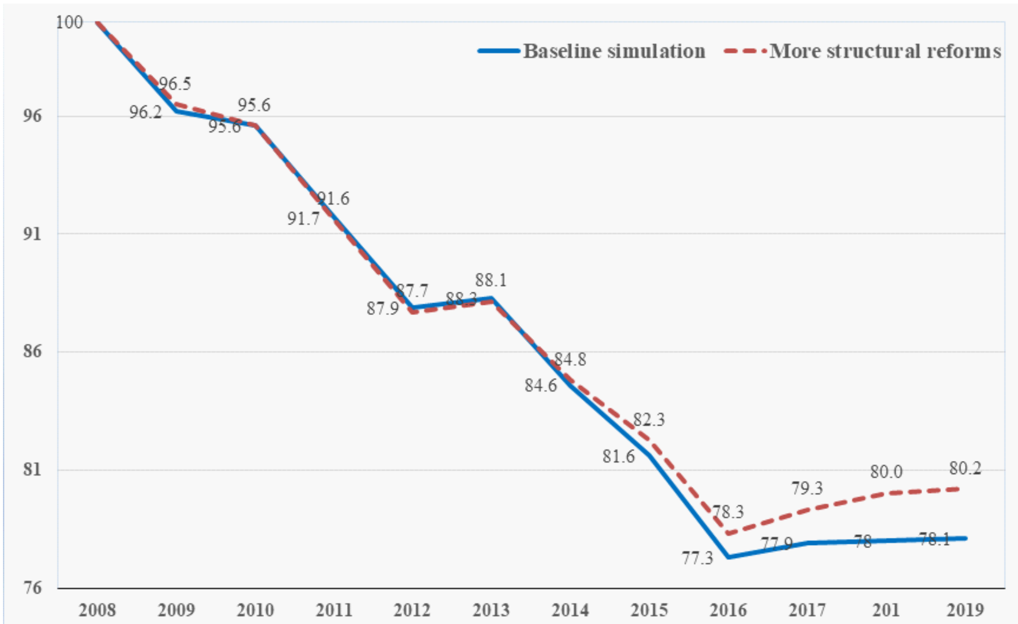
Graph 6
Less fiscal austerity - higher spending



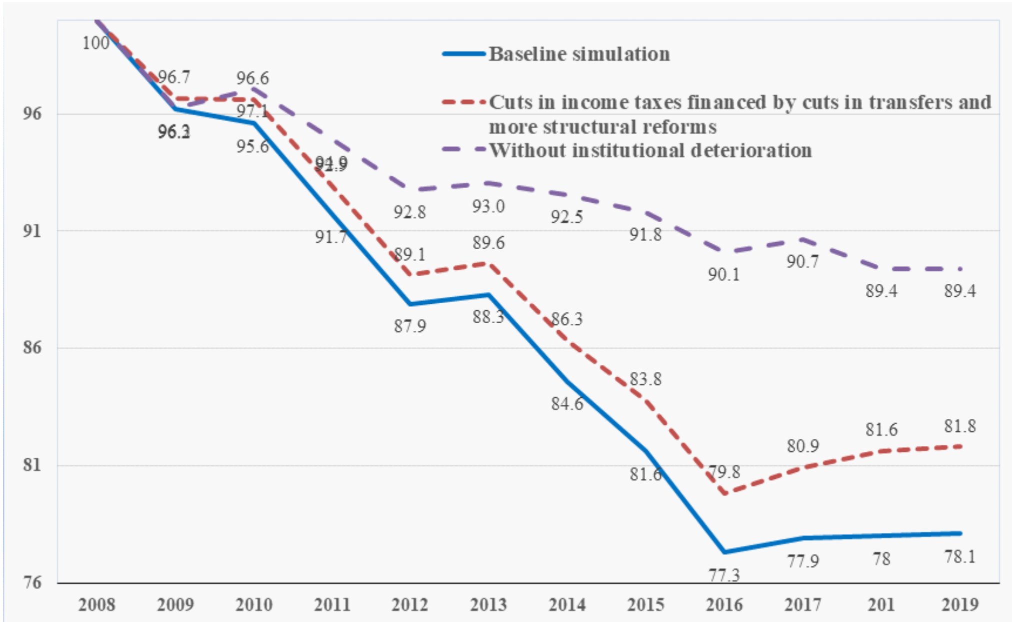
Graph 7
Alternative fiscal mixes



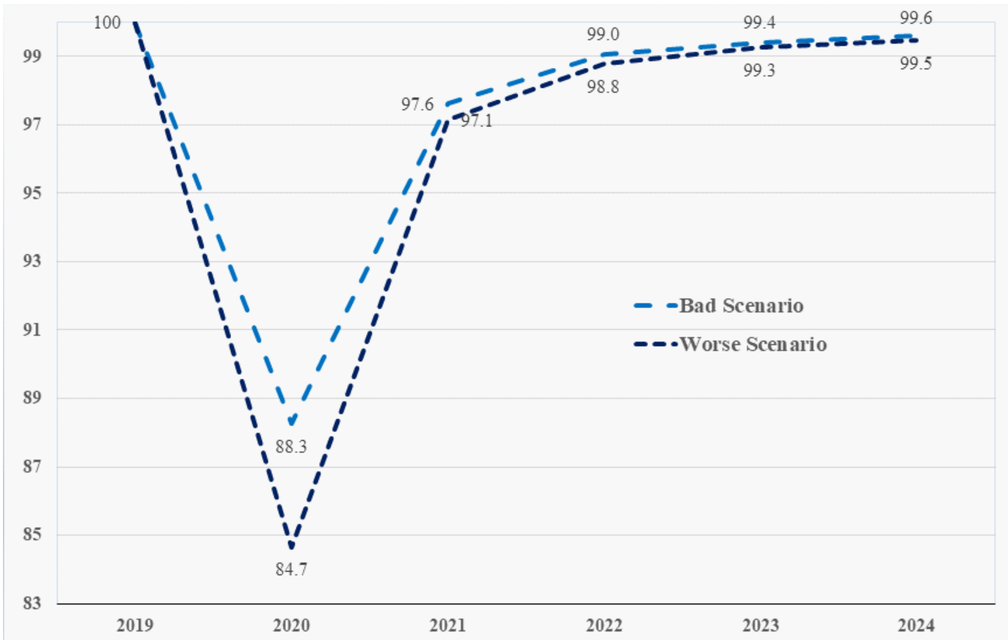
Graph 8
Stronger product market liberalization



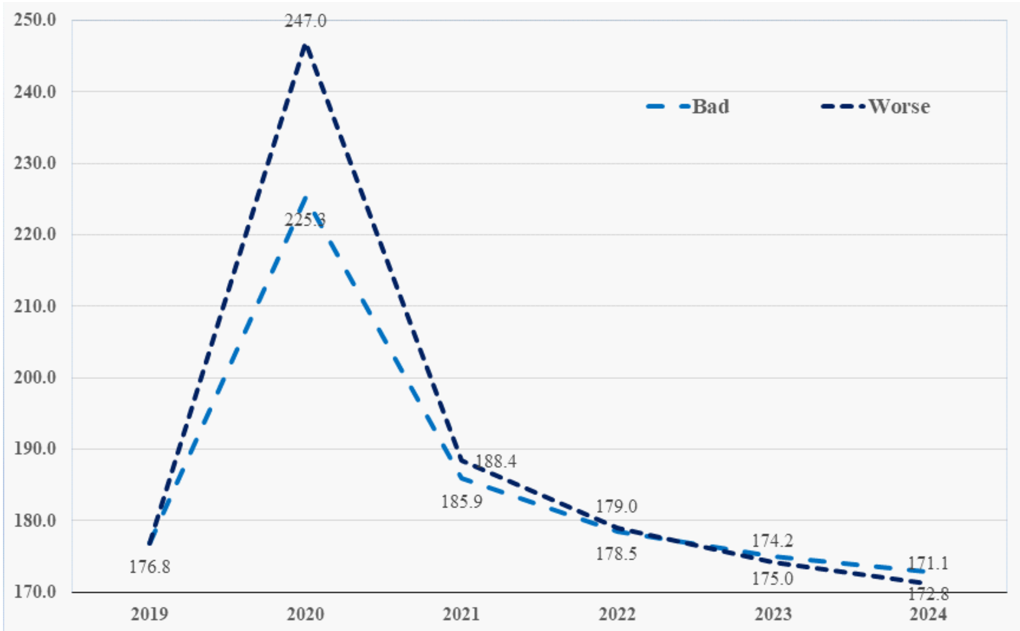
Graph 9
Putting counterfactuals together



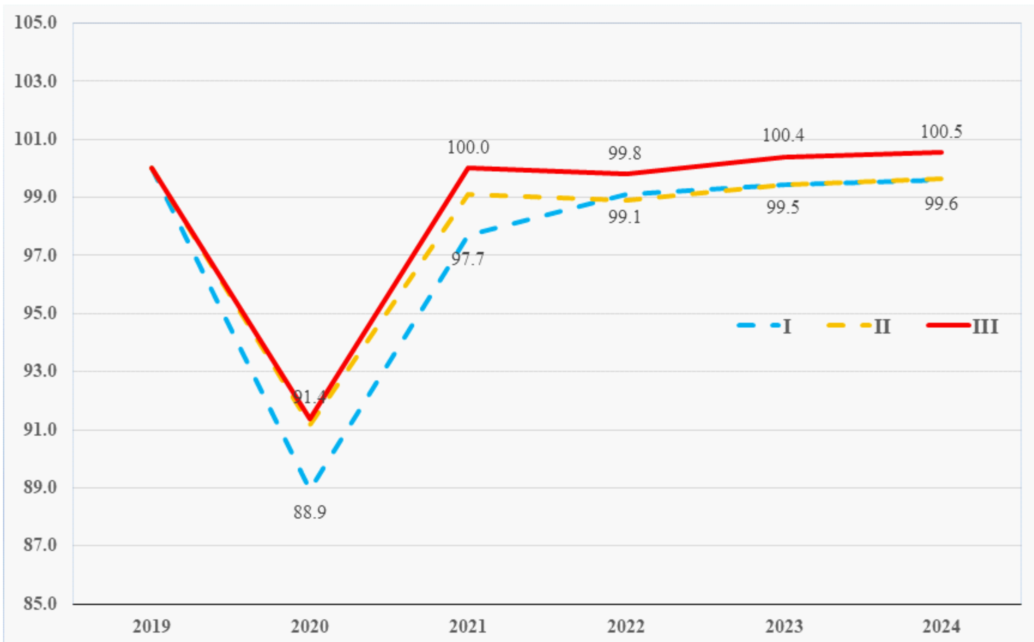
Graph 10
The economic impact of covid-19 without any response



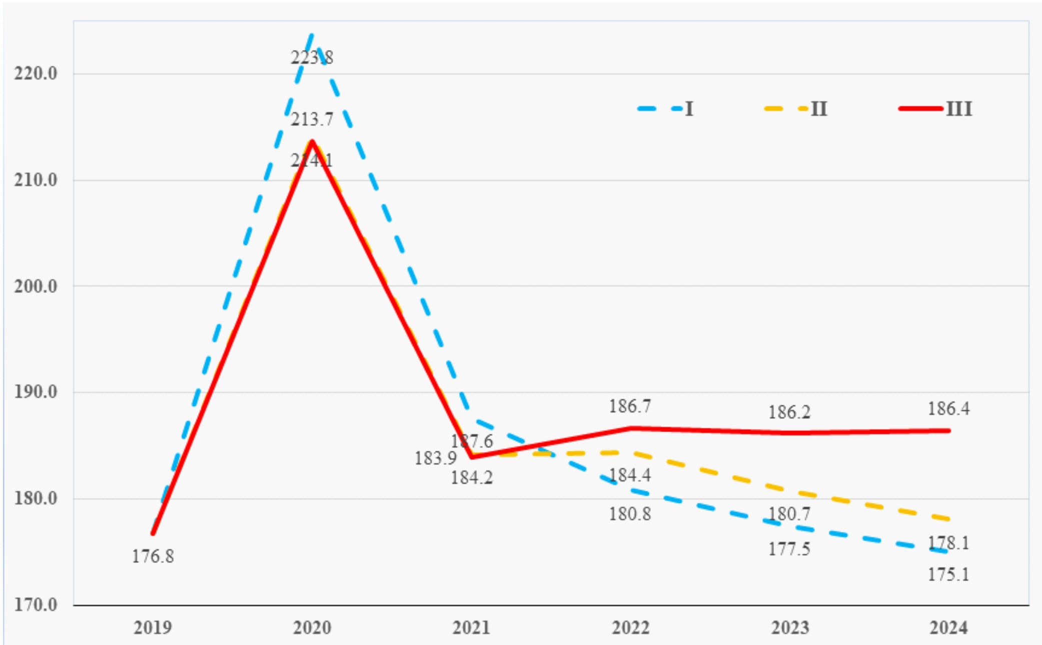
Graph 11
The public debt to output ratio without any response



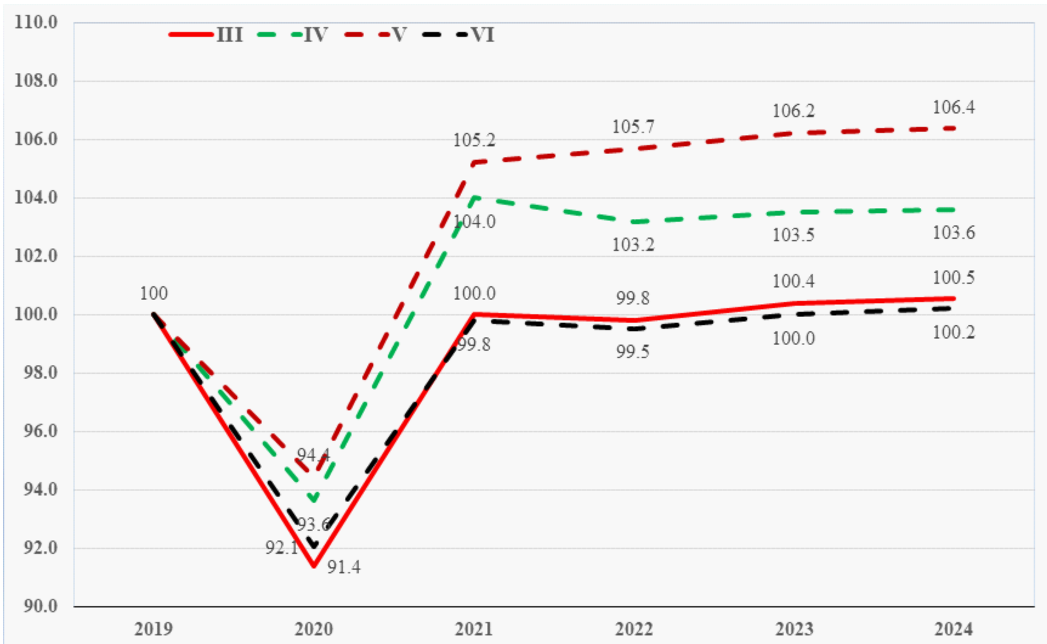
Graph 12
The economic impact of covid-19
under scenaria (I), (II) and (III)



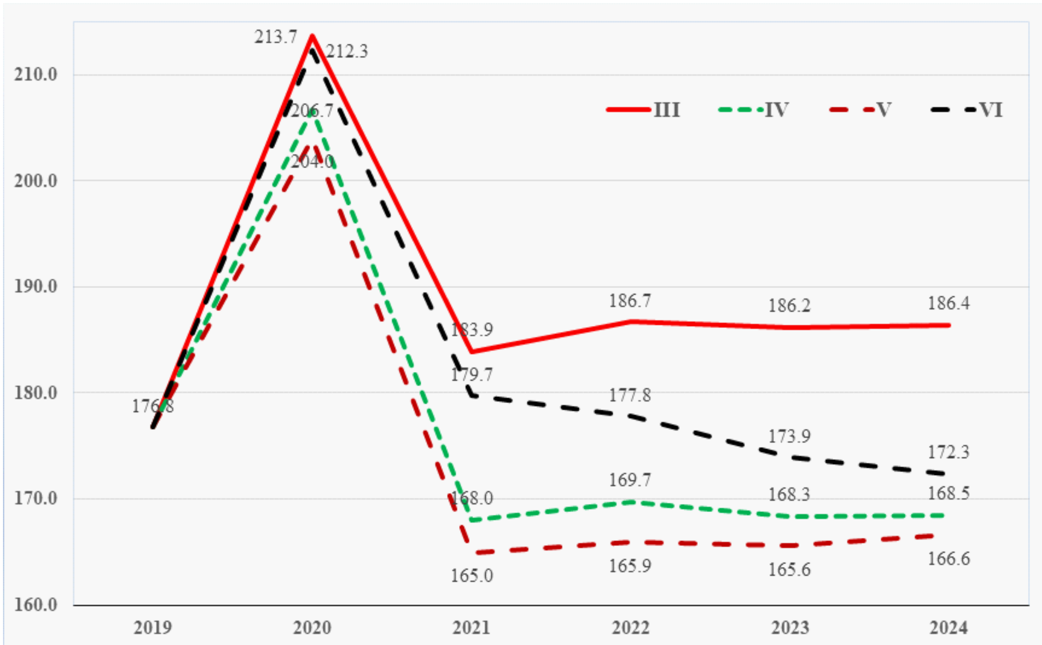
Graph 13
The public debt to output ratio
under scenaria (I), (II) and (III)



Graph 14
The economic impact of covid-19
under scenaria (IV), (V) and (VI)



Graph 15
The public debt to output ratio
under scenaria (IV), (V) and (VI)



Appendices

Appendix A: Economic agents

Appendix A provides the first-order conditions of households, private firms and private banks.

A.1 Solution of the capital owner's problem

Each k acts competitively choosing $\{c^h_{k,t},\ c^f_{k,t},\ c_{k,t},\ l_{k,t},\ s_{k,t},\ R_{k,t},\ f_{k,t},\ h_{k,t}\}^{\infty}_{t=0}$. The first-order conditions include the definition in (2), the constraints in (3a-3b) in the main text and also:

$$\frac{\mu_2}{(1-l_{k,t}-s_{k,t})} = \frac{\mu_1(1-\tau^y_t)w^k_t}{(1+\tau^c_t)c_{k,t}} \tag{A1a}$$

$$\frac{\mu_2}{(1-l_{k,t}-s_{k,t})} = \left(\frac{\mu_1}{(1+\tau^c_t)c_{k,t}}\right)\left(\frac{\gamma\Gamma^k(s_{k,t})^{\gamma-1}(1-PR_t)\frac{p^h_t}{p_t}n^k y^h_{i,t}}{n^k\Gamma^k(s_{k,t})^{\gamma}+n^w\Gamma^w(s_{w,t})^{\gamma}+n^b\Gamma^b(s_{b,t})^{\gamma}}\right) \tag{A1b}$$

$$q_t\frac{(1+\tau^c_{t+1})c_{k,t+1}}{(1+\tau^c_t)c_{k,t}} = \beta_k(q_{t+1}+\pi^i_{k,t}) \tag{A1c}$$

$$\begin{aligned}\frac{(1+\tau^c_{t+1})c_{k,t+1}}{(1+\tau^c_t)c_{k,t}}\frac{e_tp^*_t}{p_t} &= \frac{(1+\tau^c_{t+1})c_{k,t+1}}{(1+\tau^c_t)c_{k,t}}\frac{e_tp^*_t}{p_t}\times \\ \times\psi^p\left[\frac{\frac{e_tp^*_t}{p_t}\left(N^k_tf_{k,t}+F^g_t\right)}{\frac{p^h_t}{p_t}Y_t}-\overline{f}\right] &+ \beta_k\frac{e_{t+1}p^*_{t+1}}{p_{t+1}}(1+i^*_{t+1})\frac{p^*_t}{p^*_{t+1}}\end{aligned} \tag{A1d}$$

$$\frac{c^h_{k,t}}{c^f_{k,t}} = \frac{\nu}{(1-\nu)}\frac{p^f_t}{p^h_t} \tag{A1e}$$

$$\frac{\mu_3}{h_{k,t}}+\beta_k\frac{1}{(1+\tau^c_{t+1})c_{k,t+1}}\frac{p_t}{p_{t+1}} = \frac{1}{(1+\tau^c_t)c_{k,t}} \tag{A1f}$$

It also follows from the above equations that the CPI is:

$$p_t = (p^h_t)^{\nu}(p^f_t)^{1-\nu} \tag{A1g}$$

A.2 Solution of the worker's problem

Each w acts competitively choosing $\{c^h_{w,t},\ c^f_{w,t},\ c_{w,t},\ l_{w,t},\ s_{w,t},\ j_{w,t},\ h_{w,t}\}^{\infty}_{t=0}$. The first-order conditions include the definition in (6), the constraints in (7a-7b) in the main text and also:

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})} = \frac{\mu_1(1-\tau^y_t)w^w_t}{(1+\tau^c_t)c_{w,t}} \tag{A2a}$$

$$\frac{c^h_{w,t}}{c^f_{w,t}} = \frac{\nu}{(1-\nu)}\frac{p^f_t}{p^h_t} \tag{A2b}$$

$$\frac{\mu_3}{h_{w,t}} + \beta\frac{1}{(1+\tau^c_{t+1})c_{w,t+1}}\frac{p_t}{p_{t+1}} = \frac{1}{(1+\tau^c_t)c_{w,t}} \tag{A2c}$$

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})} = \left(\frac{\mu_1}{(1+\tau^c_t)c_{w,t}}\right)\left(\frac{\gamma\Gamma^w(s_{w,t})^{\gamma-1}(1-PR_t)\frac{p^h_t}{p_t}n^k y^h_{i,t}}{n^k\Gamma^k(s_{k,t})^{\gamma}+n^w\Gamma^w(s_{w,t})^{\gamma}+n^b\Gamma^b(s_{b,t})^{\gamma}}\right) \tag{A2d}$$

$$\frac{(1+\tau^c_{t+1})c_{w,t+1}}{(1+\tau^c_t)c_{w,t}} = \beta(1+i^d_{t+1})\frac{p_t}{p_{t+1}} \tag{A2e}$$

A.3 Solution of the public employee's problem

Each b acts competitively choosing $\{c^h_{b,t},\ c^f_{b,t},\ c_{b,t},\ l_{b,t},\ s_{b,t},\ j_{b,t},\ h_{b,t}\}^{\infty}_{t=0}$. The first-order conditions include the definition in (9), the constraints in (10a-10b) in the main text and also:

$$\frac{\mu_2}{(1-l_{b,t}-s_{b,t})} = \frac{\mu_1(1-\tau^y_t)w^g_t}{(1+\tau^c_t)c_{b,t}} \tag{A3a}$$

$$\frac{\mu_2}{(1-l_{b,t}-s_{b,t})} = \left(\frac{\mu_1}{(1+\tau^c_t)c_{b,t}}\right)\left(\frac{\gamma\Gamma^b(s_{b,t})^{\gamma-1}(1-PR_t)\frac{p^h_t}{p_t}n^k y^h_{i,t}}{n^k\Gamma^k(s_{k,t})^{\gamma}+n^w\Gamma^w(s_{w,t})^{\gamma}+n^b\Gamma^b(s_{b,t})^{\gamma}}\right) \tag{A3b}$$

$$\frac{c^h_{b,t}}{c^f_{b,t}} = \frac{\nu}{(1-\nu)}\frac{p^f_t}{p^h_t} \tag{A3c}$$

$$\frac{\mu_3}{h_{b,t}} + \beta\frac{1}{(1+\tau^c_{t+1})c_{b,t+1}}\frac{p_t}{p_{t+1}} = \frac{1}{(1+\tau^c_t)c_{b,t}} \tag{A3d}$$

$$\frac{(1+\tau^c_{t+1})c_{b,t+1}}{(1+\tau^c_t)c_{b,t}} = \beta(1+i^d_{t+1})\frac{p_t}{p_{t+1}} \tag{A3e}$$

A.4 Solution of the final good firm's problem

Each final good firm acts competitively. The first-order condition for $y^h_{i,t}$ gives the demand function:

$$p^h_{i,t} = p^h_t\left(\frac{y^h_{i,t}}{y^h_{h,t}}\right)^{\theta-1} \tag{A4a}$$

which in turn implies from the zero-profit condition:

$$p^h_t = \left[\sum_{i=1}^{N^i}\frac{1}{N^i}(p^h_{i,t})^{\frac{\theta}{\theta-1}}\right]^{\frac{\theta-1}{\theta}} \tag{A4b}$$

Note that, in a symmetric equilibrium, $y^h_{h,t} = y^h_{i,t}$ and $p^h_t = p^h_{i,t}$.

A.5 Solution of the intermediate goods firm's problem

The firm maximizes its stream of dividends defined in (14) and (17), subject to the production function in (15), the borrowing constraint in (16) and the inverse demand function coming from the final good firm's problem in (A4a). The first-order conditions for $\{l^w_{i,t},\, l^k_{i,t},\, m^f_{i,t},\, k_{i,t},\, L_{i,t}\}_{t=0}^{\infty}$ are respectively:

$$(1-\tau^\pi_t)w^w_t = [(1-\tau^\pi_t)PR_t\theta\frac{p^h_t}{p_t} - \frac{p^h_t}{p_t}\xi^p\left(\frac{p^h_t}{p^h_{t-1}}-1\right)\frac{p^h_t}{p^h_{t-1}}\frac{(\theta-1)\overline{y}^h_{i,t}}{y^h_{i,t}} +$$

$$+\beta_{i,t}\frac{p^h_{t+1}}{p_{t+1}}\xi^p\left(\frac{p^h_{t+1}}{p^h_t}-1\right)\frac{p^h_{t+1}}{p^h_t}\frac{(\theta-1)\overline{y}^h_{i,t+1}}{y^h_{i,t}}]\frac{(1-\sigma)(1-\alpha)A^w y^h_{i,t}}{(A^k l^k_{i,t}+A^w l^w_{i,t})} \tag{A5a}$$

$$(1-\tau^\pi_t)w^k_t = [(1-\tau^\pi_t)PR_t\theta\frac{p^h_t}{p_t} - \frac{p^h_t}{p_t}\xi^p\left(\frac{p^h_t}{p^h_{t-1}}-1\right)\frac{p^h_t}{p^h_{t-1}}\frac{(\theta-1)\overline{y}^h_{i,t}}{y^h_{i,t}} +$$

$$+\beta_{i,t}\frac{p^h_{t+1}}{p_{t+1}}\xi^p\left(\frac{p^h_{t+1}}{p^h_t}-1\right)\frac{p^h_{t+1}}{p^h_t}\frac{(\theta-1)\overline{y}^h_{i,t+1}}{y^h_{i,t}}]\frac{(1-\sigma)(1-\alpha)A^k y^h_{i,t}}{(A^k l^k_{i,t}+A^w l^w_{i,t})} \tag{A5b}$$

$$(1-\tau^\pi_t)\frac{p^f_t}{p_t} = [(1-\tau^\pi_t)PR_t\theta\frac{p^h_t}{p_t} - \frac{p^h_t}{p_t}\xi^p\left(\frac{p^h_t}{p^h_{t-1}}-1\right)\frac{p^h_t}{p^h_{t-1}}\frac{(\theta-1)\overline{y}^h_{i,t}}{y^h_{i,t}} +$$

$$+\beta_{i,t}\frac{p^h_{t+1}}{p_{t+1}}\xi^p\left(\frac{p^h_{t+1}}{p^h_t}-1\right)\frac{p^h_{t+1}}{p^h_t}\frac{(\theta-1)\overline{y}^h_{i,t+1}}{y^h_{i,t}}]\frac{(1-\sigma)\alpha y^h_{i,t}(1-\chi^p)(m^f_{i,t})^{op-1}}{\left[\chi^p(k_{i,t-1})^{op}+(1-\chi^p)(m^f_{i,t})^{op}\right]} \tag{A5c}$$

$$\frac{p^h_t}{p_t}\left[1+\xi^k\left(\frac{k_{i,t}}{k_{i,t-1}}-1\right)\right] = \beta_{i,t}\frac{p^h_{t+1}}{p_{t+1}}[1-\delta+(1-\tau^\pi_{t+1})PR_{t+1}\theta r^k_{t+1}-$$

$$-\frac{\xi^k}{2}\left(\frac{k_{i,t+1}}{k_{i,t}}-1\right)^2+\xi^k\left(\frac{k_{i,t+1}}{k_{i,t}}-1\right)\frac{k_{i,t+1}}{k_{i,t}}]-$$

$$-\beta_{i,t}\frac{p^h_{t+1}}{p_{t+1}}\xi^p\left(\frac{p^h_{t+1}}{p^h_t}-1\right)\frac{p^h_{t+1}}{p^h_t}(\theta-1)r^k_{t+1}+$$

$$+\beta_{i,t+1}\frac{p^h_{t+2}}{p_{t+2}}\xi^p\left(\frac{p^h_{t+2}}{p^h_{t+1}}-1\right)\frac{p^h_{t+2}}{p^h_{t+1}}(\theta-1)r^k_{t+1}+\beta_{i,t}N_{i,t+1}\rho^l\frac{p^h_{t+1}}{p_{t+1}} \tag{A5d}$$

$$1 = \beta_{i,t}(1+i^l_{t+1})\frac{p_t}{p_{t+1}}+N_{i,t} \tag{A5e}$$

and we also have the complementary slackness condition on the borrowing constraint (16):

$$N_{i,t}\left(L_{i,t}-\rho^l\frac{p^h_t}{p_t}k_{i,t-1}\right)=0 \tag{A5f}$$

where $N_{i,t}$ is the multiplier associated with (16) and we define $r^k_{t+1} \equiv \frac{\partial y^h_{i,t+1}}{\partial k_{k,t}} = \frac{(1-\sigma)\alpha y^h_{i,t+1}\chi^p(k_{k,t})^{op-1}}{\left[\chi^p(k_{i,t})^{op}+(1-\chi^p)(m^f_{i,t+1})^{op}\right]}$. Also, $\beta_{i,t} \equiv \frac{\beta_k(1+\tau^c_t)c_{k,t}}{(1+\tau^c_{t+1})c_{k,t+1}}$. Notice that the Euler equation for bank loans, jointly with the Euler equation for bank deposits in the savers' problem, reveals that i^l_{t+1} can differ from i^d_{t+1}, which is helpful in the private banks' optimization problem that follows below.are respectively:

A.6 Solution of the private bank's problem

Working as in Curdia and Woodford (2010, 2011), we set in each time period:

$$(1+i^d_t)\frac{p_{t-1}}{p_t}j_{p,t-1}+(1+i^z_t)\frac{p_{t-1}}{p_t}z_{p,t-1}=(1+i^l_t)\frac{p_{t-1}}{p_t}L_{p,t-1}+(1+i^*_t)\frac{p_{t-1}}{p_t}b_{p,t-1} \tag{A6a}$$

so that by leading it one period forward we have for the issuance of deposits at time t:

$$j_{p,t}=\frac{(1+i^l_{t+1})\frac{p_t}{p_{t+1}}L_{p,t}+(1+i^*_{t+1})\frac{p_t}{p_{t+1}}b_{p,t}-(1+i^z_{t+1})\frac{p_t}{p_{t+1}}z_{p,t}}{(1+i^d_{t+1})\frac{p_t}{p_{t+1}}} \tag{A6b}$$

Using (A6a) into (19), the private bank solves a static problem in each period by maximizing:

$$\pi_{p,t}\equiv j_{p,t}+z_{p,t}-L_{p,t}-b_{p,t}-\frac{p^h_t}{p_t}\Xi(L_{p,t},z_{p,t},b_{p,t}) \tag{A6c}$$

subject to the borrowing constraint in (20).

The optimality conditions for$L_{p,t}$ and $z_{p,t}$ are respectively:

$$\frac{p^h_t}{p_t}\xi^l L_{i,t}=\frac{(1+i^l_{t+1})}{(1+i^d_{t+1})}-1+N_{p,t}\rho_p \tag{A6d}$$

$$\frac{p^h_t}{p_t}\xi^z z_{p,t}=1-\frac{(1+i^z_{t+1})}{(1+i^d_{t+1})}-N_{p,t} \tag{A6e}$$

and we also have the complementary slackness condition on the borrowing constraint (20):

$$N_{p,t}\left(z_{p,t}-\rho^z(L_{p,t}+b_{p,t})\right)=0 \tag{A6f}$$

where $N_{p,t}$ is the multiplier associated with the constraint in (20).

Notice that these are well-defined supply and demand functions. Also notice, as we have pointed out in the main text, that we could also derive the optimal demand for government bonds. However, instead of choosing $b_{p,t}$, we prefer to simply set it (namely, the fraction of Greek public debt purchased by private domestic banks) exogenously as in the data.

A.7 Households' net incomes

Capital owner's net income:

$$y^{net}_{k,t}\equiv(1-\tau^y_t)w^k_t l_{k,t}+(q_t+\pi^i_{k,t})R_{k,t-1}+\pi^p_{k,t}$$

$$+\frac{e_t p_t^*}{p_t} f_{k,t} + \frac{p_{t-1}}{p_t} h_{k,t-1} + \overline{g}_t^{tr} +$$

$$+\left(\frac{\Gamma^k (s_{k,t})^\gamma}{N^k \Gamma^k (s_{k,t})^\gamma + N^w \Gamma^w (s_{w,t})^\gamma + N^b \Gamma^b (s_{b,t})^\gamma}\right)(1 - PR_t) Y_t -$$

$$-\tau_t^c \left(\frac{p_t^h}{p_t} c_{k,t}^h + \frac{p_t^f}{p_t} c_{k,t}^f\right) \tag{A7a}$$

Worker's net income:

$$y_{w,t}^{net} \equiv (1 - \tau_t^y) w_t^w l_{w,t} + (1 + i_t^d) \frac{p_{t-1}}{p_t} j_{w,t-1} + \frac{p_{t-1}}{p_t} h_{w,t-1} + \overline{g}_t^{tr} +$$

$$+\left(\frac{\Gamma^w (s_{w,t})^\gamma}{N^k \Gamma^k (s_{k,t})^\gamma + N^w \Gamma^w (s_{w,t})^\gamma + N^b \Gamma^b (s_{b,t})^\gamma}\right)(1 - PR_t) Y_t -$$

$$-\tau_t^c \left(\frac{p_t^h}{p_t} c_{w,t}^h + \frac{p_t^f}{p_t} c_{w,t}^f\right) \tag{A7b}$$

Public sector employee's net income:

$$y_{b,t}^{net} \equiv (1 - \tau_t^y) w_t^g l_{b,t} + (1 + i_t^d) \frac{p_{t-1}}{p_t} j_{b,t-1} + \frac{p_{t-1}}{p_t} h_{b,t-1} + \overline{g}_t^{tr} +$$

$$+\left(\frac{\Gamma^b (s_{b,t})^\gamma}{N^k \Gamma^k (s_{k,t})^\gamma + N^w \Gamma^w (s_{w,t})^\gamma + N^b \Gamma^b (s_{b,t})^\gamma}\right)(1 - PR_t) Y_t -$$

$$-\tau_t^c \left(\frac{p_t^h}{p_t} c_{b,t}^h + \frac{p_t^f}{p_t} c_{b,t}^f\right) \tag{A7c}$$

Appendix B: Market-clearing conditions

Recall first the definitions of populations and their fractions. That is, $N^k + N^w + N^b = N$, $n^k = \frac{N^k}{N}$, $n^b = \frac{N^b}{N}$, $n^w = \frac{N^b}{N} = 1 - n^k - n^b$. Recall also that we have assumed for notational simplicity $N^k = N^h = N^i = N^p$ and $N^b = N^g$. Then, we have the following market-clearing conditions:

In the markets for dividends and shares:

$$N^k \pi_{k,t}^i = N^i \pi_{i,t} = N^k \pi_{i,t} \tag{B1a}$$

$$N^k \pi_{k,t}^p = N^p \pi_{p,t} = N^k \pi_{p,t} \tag{B1b}$$

$$N^k R_{k,t} = N^i R_{i,t} = N^k R_{i,t} \tag{B1c}$$

In the labor market for managerial services:

$$N^k l_{k,t} = N^i l_{i,t}^k = N^k l_{i,t}^k \tag{B2}$$

In the labor market for public employees:

$$N^b l_{b,t} = N^g l_{g,t} = N^b l_{g,t} \tag{B3}$$

In the labor market for private workers:

$$N^w l_{w,t} = N^i l_{i,t}^w = N^k l_{i,t}^w \tag{B4}$$

In the bank deposit market:

$$N^p j_{p,t} = N^k j_{p,t} = N^w j_{w,t} + N^b j_{b,t} \tag{B5}$$

In the market for bank loans:

$$N^p L_{p,t} = N^k L_{p,t} = N^k L_{i,t} \tag{B6}$$

Regarding sovereign bonds purchased by domestic private agents/banks (expressed in population shares):

$$n^k b_{p,t} \equiv b_t^d = \lambda_t^d d_t \tag{B7}$$

In the money market (expressed in population shares):

$$h_t^n = n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t} \tag{B8}$$

In the market for the domestically produced good (expressed in population shares):

$$\begin{aligned} n^k y_{i,t}^h = {} & n^k c_{k,t}^h + n^w c_{w,t}^h + n^b c_{b,t}^h + n^k x_{k,t} + n^b (g_{g,t}^g + g_{g,t}^i) + c_t^{f*} + \\ & + n^k \frac{\xi^k}{2} \left(\frac{k_{k,t}}{k_{k,t-1}} - 1 \right)^2 k_{k,t-1} + n^k \frac{\xi^p}{2} \left(\frac{p_t^h}{p_{t-1}^h} - 1 \right)^2 y_{i,t}^h + \\ & + n^k \left(\frac{\xi^l}{2} (L_{i,t})^2 + \frac{\xi^z}{2} (z_{p,t})^2 + \frac{\xi^b}{2} (b_{k,t})^{-2} \right) \end{aligned} \tag{B9}$$

where c_t^{f*} denotes per capita exports to the rest of the world. Since in a small open economy this is an exogenous variable, we assume, following e.g. Lorenzoni (2014, p. 698), that $c_t^{f*} = \Theta \left(\frac{p_t^h}{p_t^f} \right)^{-\vartheta}$, where $\Theta, \vartheta > 0$ are parameters.

Appendix C: Macroeconomic system

Collecting all equations, the macroeconomic system that we solve numerically consists of the following equations:

Capital owner

$$c_{k,t} = \frac{(c^h_{k,t})^{\nu}(c^f_{k,t})^{1-\nu}}{\nu^{\nu}(1-\nu)^{1-\nu}} \tag{S1}$$

$$\frac{\mu_2}{(1-l_{k,t}-s_{k,t})} = \frac{\mu_1(1-\tau^y_t)w^k_t}{(1+\tau^c_t)c_{k,t}} \tag{S2}$$

$$\frac{\mu_2}{(1-l_{k,t}-s_{k,t})} = \left(\frac{\mu_1}{(1+\tau^c_t)c_{k,t}}\right)\left(\frac{\gamma\Gamma^k(s_{k,t})^{\gamma-1}(1-PR_t)\frac{p^h_t}{p_t}n^k y^h_{i,t}}{n^k\Gamma^k(s_{k,t})^{\gamma}+n^w\Gamma^w(s_{w,t})^{\gamma}+n^b\Gamma^b(s_{b,t})^{\gamma}}\right) \tag{S3}$$

$$q_t\frac{(1+\tau^c_{t+1})c_{k,t+1}}{(1+\tau^c_t)c_{k,t}} = \beta_k(q_{t+1}+\pi_{i,t}) \tag{S4}$$

$$\frac{(1+\tau^c_{t+1})c_{k,t+1}}{(1+\tau^c_t)c_{k,t}}\frac{e_t p^*_t}{p_t} = \frac{(1+\tau^c_{t+1})c_{k,t+1}}{(1+\tau^c_t)c_{k,t}}\frac{e_t p^*_t}{p_t}\times$$

$$\times\psi^p\left[\frac{\frac{e_t p^*_t}{p_t}\left(n^k_t f^t_k+\lambda^g_t d_t\right)}{\frac{p^h_t}{p_t}n^k y^h_{i,t}}-\overline{f}\right]+\beta_k\frac{e_{t+1}p^*_{t+1}}{p_{t+1}}(1+i^*_{t+1})\frac{p^*_t}{p^*_{t+1}} \tag{S5}$$

$$\frac{c^h_{k,t}}{c^f_{k,t}} = \frac{\nu}{(1-\nu)}\frac{p^f_t}{p^h_t} \tag{S6}$$

$$\frac{\mu_3}{h_{k,t}}+\beta_k\frac{1}{(1+\tau^c_{t+1})c_{k,t+1}}\frac{p_t}{p_{t+1}} = \frac{1}{(1+\tau^c_t)c_{k,t}} \tag{S7}$$

Worker

$$c_{w,t} = \frac{(c^h_{w,t})^{\nu}(c^f_{w,t})^{1-\nu}}{\nu^{\nu}(1-\nu)^{1-\nu}} \tag{S8}$$

$$(1+\tau^c_t)\left(\frac{p^h_t}{p_t}c^h_{w,t}+\frac{p^f_t}{p_t}c^f_{w,t}\right)+j_{w,t}+h_{w,t}\equiv$$

$$\equiv(1-\tau^y_t)w^w_t l_{w,t}+(1+i^d_t)\frac{p_{t-1}}{p_t}j_{w,t-1}+\frac{p_{t-1}}{p_t}h_{w,t-1}+\overline{g}^{tr}_t+$$

$$+\frac{\Gamma^w(s_{w,t})^{\gamma}(1-PR_t)\frac{p^h_t}{p_t}n^k y^h_{i,t}}{n^k\Gamma^k(s_{k,t})^{\gamma}+n^w\Gamma^w(s_{w,t})^{\gamma}+n^b\Gamma^b(s_{b,t})^{\gamma}} \tag{S9}$$

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})} = \frac{\mu_1(1-\tau^y_t)w^w_t}{(1+\tau^c_t)c_{w,t}} \tag{S10}$$

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})} = \left(\frac{\mu_1}{(1+\tau_t^c)c_{w,t}}\right)\left(\frac{\gamma\Gamma^w(s_{w,t})^{\gamma-1}(1-PR_t)\frac{p_t^h}{p_t}n^k y_{i,t}^h}{n^k\Gamma^k(s_{k,t})^\gamma + n^w\Gamma^w(s_{w,t})^\gamma + n^b\Gamma^b(s_{b,t})^\gamma}\right) \tag{S11}$$

$$\frac{c_{w,t}^h}{c_{w,t}^f} = \frac{\nu}{(1-\nu)}\frac{p_t^f}{p_t^h} \tag{S12}$$

$$\frac{\mu_3}{h_{w,t}} + \beta\frac{1}{(1+\tau_{t+1}^c)c_{w,t+1}}\frac{p_t}{p_{t+1}} = \frac{1}{(1+\tau_t^c)c_{w,t}} \tag{S13}$$

$$\frac{(1+\tau_{t+1}^c)c_{w,t+1}}{(1+\tau_t^c)c_{w,t}} = \beta(1+i_{t+1}^d)\frac{p_t}{p_{t+1}} \tag{S14}$$

Public employee

$$c_{b,t} = \frac{(c_{b,t}^h)^\nu(c_{b,t}^f)^{1-\nu}}{\nu^\nu(1-\nu)^{1-\nu}} \tag{S15}$$

$$\begin{aligned}(1+\tau_t^c)\left(\frac{p_t^h}{p_t}c_{b,t}^h + \frac{p_t^f}{p_t}c_{b,t}^f\right) + j_{b,t} + h_{b,t} =\\ = (1-\tau_t^y)w_t^g l_{b,t} + (1+i_t^d)\frac{p_{t-1}}{p_t}j_{b,t-1} + \frac{p_{t-1}}{p_t}h_{b,t-1} + \overline{g}_t^{tr} +\\ + \frac{\Gamma^b(s_{b,t})^\gamma(1-PR_t)\frac{p_t^h}{p_t}n^k y_{i,t}^h}{n^k\Gamma^k(s_{k,t})^\gamma + n^w\Gamma^w(s_{w,t})^\gamma + n^b\Gamma^b(s_{b,t})^\gamma}\end{aligned} \tag{S16}$$

$$\frac{\mu_2}{(1-l_{b,t}-s_{b,t})} = \frac{\mu_1(1-\tau_t^y)w_t^g}{(1+\tau_t^c)c_{b,t}} \tag{S17}$$

$$\frac{\mu_2}{(1-l_{b,t}-s_{b,t})} = \left(\frac{\mu_1}{(1+\tau_t^c)c_{b,t}}\right)\left(\frac{\gamma\Gamma^b(s_{b,t})^{\gamma-1}(1-PR_t)\frac{p_t^h}{p_t}n^k y_{i,t}^h}{n^k\Gamma^k(s_{k,t})^\gamma + n^w\Gamma^w(s_{w,t})^\gamma + n^b\Gamma^b(s_{b,t})^\gamma}\right) \tag{S18}$$

$$\frac{c_{b,t}^h}{c_{b,t}^f} = \frac{\nu}{(1-\nu)}\frac{p_t^f}{p_t^h} \tag{S19}$$

$$\frac{\mu_3}{h_{b,t}} + \beta\frac{1}{(1+\tau_{t+1}^c)c_{b,t+1}}\frac{p_t}{p_{t+1}} = \frac{1}{(1+\tau_t^c)c_{b,t}} \tag{S20}$$

and (instead of having a second Euler equation for bank deposits similar to (S.14) that would create indeterminacy problems in steady state) we set:

$$j_{b,t} \equiv n^k j_{p,t} \tag{S21}$$

Price indexes

$$p_t = (p_t^h)^{\nu}(p_t^f)^{1-\nu} \tag{S22}$$

$$p_t^f = e_t p_t^{h*} \tag{S23}$$

Private (intermediate goods) firms

$$y_{i,t}^h = A^p \left(\frac{n^g y_{g,t}^g}{n^k}\right)^{\sigma} \left[\left(\chi^p (k_{i,t-1})^{op} + (1-\chi^p)(m_{i,t}^f)^{op}\right)^{\frac{\alpha}{op}} \left(A^k l_{k,t} + A^w \frac{n_t^{w,e} n^w l_{w,t}}{n^k}\right)^{1-\alpha}\right]^{1-\sigma} \tag{S24}$$

$$(1-\tau_t^{\pi})w_t^w = [(1-\tau_t^{\pi})PR_t\theta\frac{p_t^h}{p_t} - \frac{p_t^h}{p_t}\xi^p\left(\frac{p_t^h}{p_{t-1}^h}-1\right)\frac{p_t^h}{p_{t-1}^h}(\theta-1)+$$

$$+\beta_{i,t}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta-1)y_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)(1-\alpha)A^w y_{i,t}^h}{(A^k l_{k,t} + A^w \frac{n_t^{w,e} n^w l_{w,t}}{n^k})} \tag{S25}$$

$$(1-\tau_t^{\pi})w_t^k = [(1-\tau_t^{\pi})PR_t\theta\frac{p_t^h}{p_t} - \frac{p_t^h}{p_t}\xi^p\left(\frac{p_t^h}{p_{t-1}^h}-1\right)\frac{p_t^h}{p_{t-1}^h}(\theta-1)+$$

$$+\beta_{i,t}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta-1)y_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)(1-\alpha)A^k y_{i,t}^h}{(A^k l_{k,t} + A^w \frac{n_t^{w,e} n^w l_{w,t}}{n^k})} \tag{S26}$$

$$\frac{p_t^h}{p_t}\left[1+\xi^k\left(\frac{k_{i,t}}{k_{i,t-1}}-1\right)\right] = \beta_{i,t}\frac{p_{t+1}^h}{p_{t+1}}[1-\delta+(1-\tau_{t+1}^{\pi})PR_{t+1}\theta r_{t+1}^k -$$

$$-\frac{\xi^k}{2}\left(\frac{k_{i,t+1}}{k_{i,t}}-1\right)^2 + \xi^k\left(\frac{k_{i,t+1}}{k_{i,t}}-1\right)\frac{k_{i,t+1}}{k_{i,t}}]-$$

$$-\beta_{i,t}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}(\theta-1)r_{t+1}^k+$$

$$+\beta_{i,t+1}\frac{p_{t+2}^h}{p_{t+2}}\xi^p\left(\frac{p_{t+2}^h}{p_{t+1}^h}-1\right)\frac{p_{t+2}^h}{p_{t+1}^h}(\theta-1)r_{t+1}^k + N_{i,t}\rho^l\frac{p_t^h}{p_t} \tag{S27}$$

$$(1-\tau_t^{\pi})\frac{p_t^f}{p_t} = [(1-\tau_t^{\pi})PR_t\theta\frac{p_t^h}{p_t} - \frac{p_t^h}{p_t}\xi^p\left(\frac{p_t^h}{p_{t-1}^h}-1\right)\frac{p_t^h}{p_{t-1}^h}(\theta-1)+$$

$$+\beta_{i,t}\frac{p_{t+1}^h}{p_{t+1}}\xi^p\left(\frac{p_{t+1}^h}{p_t^h}-1\right)\frac{p_{t+1}^h}{p_t^h}\frac{(\theta-1)y_{i,t+1}^h}{y_{i,t}^h}]\frac{(1-\sigma)\alpha y_{i,t}^h(1-\chi^p)(m_{i,t}^f)^{op-1}}{\left[\chi^p(k_{i,t-1})^{op}+(1-\chi^p)(m_{i,t}^f)^{op}\right]} \tag{S28}$$

$$k_{k,t} = (1-\delta)k_{k,t-1} + x_{k,t} \tag{S29}$$

$$\pi_{i,t} \equiv (1-\tau_t^{\pi})\left[PR_t \frac{p_t^h}{p_t} y_{i,t}^h - w_t^w \frac{n_t^{w,e} n^w}{n^k} l_{w,t} - w_t^k l_{k,t} - \frac{p_t^f}{p_t} m_{i,t}^f\right] -$$

$$-\frac{p_t^h}{p_t}\left[k_{k,t} - (1-\delta)k_{k,t-1}\right] - \frac{p_t^h}{p_t}\frac{\xi^k}{2}\left(\frac{k_{k,t}}{k_{k,t-1}} - 1\right)^2 k_{k,t-1} - \frac{p_t^h}{p_t}\frac{\xi^p}{2}\left(\frac{p_t^h}{p_{t-1}^h} - 1\right)^2 y_{i,t}^h +$$

$$+\left(L_{i,t} - (1+i_t^l)\frac{p_{t-1}}{p_t} L_{i,t-1}\right) \tag{S30}$$

$$1 = \beta_{i,t}(1+i_{t+1}^l)\frac{p_t}{p_{t+1}} + N_{i,t} \tag{S31}$$

$$N_{i,t}\left(L_{i,t} - \rho^l \frac{p_t^h}{p_t} k_{i,t}\right) = 0 \tag{S32}$$

where we use $r_{t+1}^k \equiv \frac{\partial y_{i,t+1}^h}{\partial k_{k,t}} = \frac{(1-\sigma)\alpha y_{i,t+1}^h \chi^p (k_{k,t})^{op-1}}{\left[\chi^p (k_{i,t})^{op} + (1-\chi^p)(m_{i,t+1}^f)^{op}\right]}$, $\beta_{i,t} \equiv \frac{\beta_k (1+\tau_t^c) c_{k,t}}{(1+\tau_{t+1}^c) c_{k,t+1}}$ and $\beta_{i,t+1} \equiv \frac{(\beta_k)^2 (1+\tau_{t+1}^c) c_{k,t+1}}{(1+\tau_{t+2}^c) c_{k,t+2}}$.

Private banks

$$\pi_{p,t} \equiv j_{p,t} + z_{p,t} - L_{i,t} - b_{k,t} - \frac{p_t^h}{p_t}\left(\frac{\xi^l}{2}(L_{i,t})^2 + \frac{\xi^z}{2}(z_{p,t})^2 + \frac{\xi^b}{2}(b_{k,t})^{-2}\right) \tag{S33}$$

$$j_{p,t} = \frac{(1+i_{t+1}^l)\frac{p_t}{p_{t+1}} L_{i,t} + (1+i_{t+1}^*)\frac{p_t}{p_{t+1}} b_{k,t} - (1+i_{t+1}^z)\frac{p_t}{p_{t+1}} z_{p,t}}{(1+i_{t+1}^d)\frac{p_t}{p_{t+1}}} \tag{S34}$$

$$\frac{p_t^h}{p_t}\xi^l L_{i,t} = \frac{(1+i_{t+1}^l)}{(1+i_{t+1}^d)} - 1 + N_{p,t}\rho_p \tag{S35}$$

$$\frac{p_t^h}{p_t}\xi^z z_{p,t} = 1 - \frac{(1+i_{t+1}^z)}{(1+i_{t+1}^d)} - N_{p,t} \tag{S36}$$

$$N_{p,t}\left(\mathbf{z}_{p,t} - \boldsymbol{\rho}^z(\mathbf{L}_{p,t} + \mathbf{b}_{p,t})\right) = 0 \tag{S37}$$

where:

$$n^k j_{p,t} = n^w j_{w,t} + n^b j_{b,t} \tag{S38}$$

and where we use $n^k b_{k,t} = n^p b_{p,t} = b_t^d = \lambda_t^d d_t = (1 - \lambda_t^{ncb} - \lambda_t^g - \lambda_t^{eu}) d_t$ at each t.

State firms

$$y_{g,t}^g = A^g\left(\chi^g (k_{g,t-1}^g)^{og} + (1-\chi^g)(m_{g,t}^g)^{og}\right)^{\frac{\theta_1}{og}} (l_{b,t})^{\theta_2}\left(g_{g,t}^g\right)^{1-\theta_1-\theta_2} \tag{S39}$$

$$k_{g,t}^g = (1-\delta^g)k_{g,t-1}^g + g_{g,t}^i \tag{S40}$$

Consolidated government budget constraint

$$\overline{g}_t^{tr} + (1+i_t^*)\frac{p_{t-1}}{p_t}(1-\lambda_{t-1}^{ncb}-\lambda_{t-1}^{g}-\lambda_{t-1}^{eu})d_{t-1}+$$

$$+(1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^{g}d_{t-1}+(1+i^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^{eu}d_{t-1}+$$

$$+n^b\left[w_t^g l_{g,t}^g + \frac{p_t^h}{p_t}\left(g_{g,t}^g + g_{g,t}^i\right) + \frac{p_t^f}{p_t}m_{g,t}^g\right]+$$

$$+\frac{p_t^h}{p_t}\frac{\psi^g}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t}+\lambda_t^g d_t\right)}{\frac{p_t^h}{p_t}n^k y_{i,t}^h}-\overline{f}\right]^2 n^k y_{i,t}^h = (1-\lambda_t^{ncb})d_t + \frac{T_t}{N}+$$

$$+n^k h_{k,t} + n^w h_{w,t} + n^b h_{b,t} - \frac{p_{t-1}}{p_t}(n^k h_{k,t-1}+n^w h_{w,t-1}+n^b h_{b,t-1})-$$

$$-n^k\left(z_{p,t}-\frac{P_{t-1}}{P_t}z_{p,t-1}\right)+\left(t\arg_t - \frac{P_{t-1}}{P_t}t\arg_{t-1}\right) \tag{S41}$$

where we use $n^k b_{k,t} = b_t^d = \lambda_t^d d_t = (1-\lambda_t^{ncb}-\lambda_t^g-\lambda_t^{eu})d_t$ at each t.

Gross Domestic Product (GDP) identity

$$n^k y_{i,t}^h = n^k c_{k,t}^h + n^w c_{w,t}^h + n^b c_{b,t}^h + n^k x_{k,t} + n^b(g_{g,t}^g + g_{g,t}^i) + c_t^{f*}+$$

$$+n^k\frac{\xi^k}{2}\left(\frac{k_{k,t}}{k_{k,t-1}}-1\right)^2 k_{k,t-1} + n^k\frac{\xi^p}{2}\left(\frac{p_t^h}{p_{t-1}^h}-1\right)^2 y_{i,t}^h+$$

$$+n^k\left(\frac{\xi^l}{2}(L_{i,t})^2 + \frac{\xi^z}{2}(z_{p,t})^2 + \frac{\xi^b}{2}(b_{k,t})^{-2}\right) \tag{S42}$$

where c_t^{f*} is exports to the rest of the world (defined below).

Balance of payments (economy's resource constraint)

$$\frac{p_t^f}{p_t}\left(n^k c_{k,t}^f + n^w c_{w,t}^f + n^b c_{b,t}^f + n^k m_{i,t}^f + n^b m_{g,t}^g\right) - \frac{p_t^h}{p_t}c_t^{f*}+$$

$$+(1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}n^k f_{k,t-1}+$$

$$+(1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^{g}d_{t-1}+$$

$$+(1+i^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^{eu}d_{t-1}+$$

$$+\frac{p_t^h}{p_t}\frac{\psi^p}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t}+\lambda_t^g d_t\right)}{\frac{p_t^h}{p_t}n^k y_{i,t}^h}-\overline{f}\right]^2 n^k y_{i,t}^h+$$

$$+\frac{p_t^h}{p_t}\frac{\psi^g}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t}+\lambda_t^g d_t\right)}{\frac{p_t^h}{p_t}n^k y_{i,t}^h}-\overline{f}\right]^2 n^k y_{i,t}^h=$$

$$=\frac{e_t p_t^*}{p_t}n^k f_{k,t}+\lambda_t^g d_t+\lambda_t^{eu} d_t+\left(t\arg_t-\frac{P_{t-1}}{P_t}t\arg_{t-1}\right) \tag{S43}$$

Tax revenues

$$\frac{T_t}{N}\equiv\tau_t^c[n^k(\frac{p_t^h}{p_t}c_{k,t}^h+\frac{p_t^f}{p_t}c_{k,t}^f)+n^w(\frac{p_t^h}{p_t}c_{w,t}^h+\frac{p_t^f}{p_t}c_{w,t}^f)+$$

$$+n^b(\frac{p_t^h}{p_t}c_{b,t}^h+\frac{p_t^f}{p_t}c_{b,t}^f)]+\tau_t^y n^k w_t^k l_{k,t}+\tau_t^y n_t^{w,e} n^w w_t^w l_{w,t}+$$

$$+\tau_t^y n^b w_t^g l_{b,t}+\tau_t^\pi n^k\left[PR_t\frac{p_t^h}{p_t}y_{i,t}^h-w_t^w\frac{n_t^{w,e}n^w}{n^k}l_{w,t}-w_t^k l_{k,t}-\frac{p_t^f}{p_t}m_{i,t}^f\right] \tag{S44}$$

Exports

$$c_t^{f*}=\Theta\left(\frac{p_t^h}{p_t^f}\right)^{-\vartheta} \tag{S45}$$

Public spending ratios

$$w_t^g=\frac{s_t^w\frac{p_t^h}{p_t}n^k y_{i,t}^h}{n^b l_{b,t}} \tag{S46}$$

$$g_{g,t}^g=\frac{s_t^g n^k y_{i,t}^h}{n^b} \tag{S47}$$

$$g_{g,t}^i=\frac{s_t^i n^k y_{i,t}^h}{n^b} \tag{S48}$$

$$\overline{g}_t^{tr}=s_t^{tr}\frac{p_t^h}{p_t}n^k y_{i,t}^h \tag{S49}$$

$$m_{g,t}^g=\frac{p_t^h}{p_t^f}\frac{s_t^m n^k y_{i,t}^h}{n^b} \tag{S50}$$

Country's interest rate

$$i_t^* = i^* + \psi^i \left(\exp\left(\frac{d_t}{\frac{p_t^h}{p_t} n^k y_{i,t}^h} - \overline{d}\right) - 1 \right) \tag{S51}$$

We therefore have a dynamic system of 51 equations, (S1)-(S51), in 51 variables. The latter are the paths of $\{c_{k,t},\ c_{k,t}^h,\ c_{k,t}^f\}_{t=0}^{\infty}$, $\{c_{w,t},\ c_{w,t}^h,\ c_{w,t}^f\}_{t=0}^{\infty}$, $\{c_{b,t},\ c_{b,t}^h,\ c_{b,t}^f\}_{t=0}^{\infty}$, $\{l_{k,t},\ l_{w,t},\ l_{b,t}\}_{t=0}^{\infty}$, $\{h_{k,t},\ h_{w,t},\ h_{bt}\}_{t=0}^{\infty}$, $\{s_{k,t},\ s_{w,t},\ s_{bt}\}_{t=0}^{\infty}$, $\{f_{k,t},\ j_{w,t},\ j_{bt}\}_{t=0}^{\infty}$, $\{y_{i,t}^h,\ k_{k,t},\ x_{k,t},\ m_{i,t}^f,\ \pi_{i,t},\ w_t^k,\ w_t^w,\ L_{i,t},\ N_{i,t}\}_{t=0}^{\infty}$, $\{\pi_{p,t},\ j_{p,t},\ z_{p,t},\ N_{p,t}\}_{t=0}^{\infty}$, $\left\{y_{g,t}^g,\ k_{g,t}^g\right\}_{t=0}^{\infty}$, $\{p_t,\ p_t^h,\ p_t^f,\ i_t^d,\ i_t^l,\ i_t^*,\ q_t\}_{t=0}^{\infty}$, $\left\{w_t^g,\ g_{g,t}^g,\ g_{g,t}^i,\ \overline{g}_t^{tr},\ m_{g,t}^g\right\}_{t=0}^{\infty}$, $\{targ_t\}_{t=0}^{\infty}$, $\{\frac{T_t}{N}\}_{t=0}^{\infty}$, $\{c_t^{f*}\}_{t=0}^{\infty}$. This is given the paths of the exogenously set policy variables, $\{\tau_t^c,\ \tau_t^y,\ \tau_t^\pi,\ s_t^w,\ s_t^g,\ s_t^i,\ s_t^{tr},\ s_t^m\}_{t=0}^{\infty}$, $\{\lambda_t^g,\ \lambda_t^{eu},\ \lambda_t^{ncb},\ \frac{d_t}{\frac{p_t^h}{p_t} n^k y_{i,t}^h},\ i_t^z\}_{t=0}^{\infty}$, the path of the degree of property rights, $\{PR_t\}_{t=0}^{\infty}$, and world prices $\{p_t^{h*},\ p_t^{f*},\ p_t^*\}_{t=0}^{\infty}$. The data used for the specification of the time-paths of the exogenously set policy instruments and the index of property rights used in the solutions are described in subsection 3.2 in the main text.

Transformed variables

For convenience, we re-express some variables. We define $\frac{p_t^f}{p_t^h} \equiv TT_t$ to be the terms of trade (an increase means an improvement in competitiveness vis-à-vis the rest of the world). Then, we have $\frac{p_t^h}{p_t} = (TT_t)^{\nu-1}$, $\frac{p_t^f}{p_t} = (TT_t)^{\nu}$, $\frac{e_t p_t^*}{p_t} = (TT_t)^{2\nu-1}$, $\Pi_t \equiv \frac{p_t}{p_{t-1}} = \Pi_t^h \left(\frac{TT_t}{TT_{t-1}}\right)^{1-\nu}$ and $\frac{TT_t}{TT_{t-1}} = \frac{e_t}{e_{t-1}} \frac{\Pi_t^{h*}}{\Pi_t^h}$, where $\Pi_t^h \equiv \frac{p_t^h}{p_{t-1}^h}$. Also, $\frac{e_t}{e_{t-1}}$ is the gross exchange rate depreciation which is set at one all the time. Hence, in the final system, we have $\Pi_t = \Pi_t^h \left(\frac{TT_t}{TT_{t-1}}\right)^{1-\nu}$ and $\frac{TT_t}{TT_{t-1}} = \frac{e_t}{e_{t-1}} \frac{\Pi_t^{h*}}{\Pi_t^h}$ and, in all other equations, we use the transformations $\frac{p_t^h}{p_t} = (TT_t)^{\nu-1}$, $\frac{p_t^f}{p_t} = (TT_t)^{\nu}$, $\frac{e_t p_t^*}{p_t} = (TT_t)^{2\nu-1}$. In other words, regarding prices, instead of $\{p_t,\ p_t^h,\ p_t^f\}_{t=0}^{\infty}$, now the endogenous variables are $\left\{TT_t,\ \Pi_t^h,\ \Pi_t\right\}_{t=0}^{\infty}$. Recall that, in a small open economy, $\Pi_t^{h*} \equiv \frac{p_t^{h*}}{p_{t-1}^{h*}}$ is exogenous (we set it at 1 all the time), while $\Pi_t^* \equiv \frac{p_t^*}{p_{t-1}^*}$ can also be treated for simplicity as exogenous (we set it at 1 all the time) or, more generally, if we use $p_t^* = (p_t^{h*})^{\nu}(p_t^{f*})^{1-\nu}$, it can be written as $\Pi_t^* \equiv \frac{p_t^*}{p_{t-1}^*} = (\Pi_t^{h*})^{\nu} \left(\Pi_t^h\right)^{1-\nu}$(where we have set $\frac{e_t}{e_{t-1}} = 1$); in our solutions, we simply set $\Pi_t^* \equiv \frac{p_t^*}{p_{t-1}^*} = 1$ all the time.

Appendix D: Modelling the economic impact of covid-19

This appendix presents what changes in the above model as a result of covid-19. The changes have been discussed informally in the main text.

Given the labor supply shock, the budget constraints of the three types of households change to:

$$
\begin{aligned}
&(1+\tau_t^c)\left(\frac{p_t^h}{p_t}c_{k,t}^h+\frac{p_t^f}{p_t}c_{k,t}^f\right)+(1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}f_{k,t-1}+\\
&+q_t R_{k,t}+\frac{p_t^h}{p_t}\psi^p(.)+h_{k,t}\equiv\\
&\equiv(1-\tau_t^y)w_t^k\Phi_t l_{k,t}+g_{k,t}^{cov}+(q_t+\pi_{k,t}^i)R_{k,t-1}+\pi_{k,t}^p\\
&+\frac{e_t p_t^*}{p_t}f_{k,t}+\frac{p_{t-1}}{p_t}h_{k,t-1}+\overline{g}_t^{tr}+\\
&+\left(\frac{\Gamma^k(s_{k,t})^\gamma}{N^k\Gamma^k(s_{k,t})^\gamma+N^w\Gamma^w(s_{w,t})^\gamma+N^b\Gamma^b(s_{b,t})^\gamma}\right)(1-PR_t)Y_t
\end{aligned}
\tag{D1a}
$$

$$
\begin{aligned}
&(1+\tau_t^c)\left(\frac{p_t^h}{p_t}c_{w,t}^h+\frac{p_t^f}{p_t}c_{w,t}^f\right)+j_{w,t}+h_{w,t}\equiv\\
&\equiv(1-\tau_t^y)w_t^w\Phi_t l_{w,t}+g_{w,t}^{cov}+(1+i_t^d)\frac{p_{t-1}}{p_t}j_{w,t-1}+\frac{p_{t-1}}{p_t}h_{w,t-1}+\overline{g}_t^{tr}+\\
&+\left(\frac{\Gamma^w(s_{w,t})^\gamma}{N^k\Gamma^k(s_{k,t})^\gamma+N^w\Gamma^w(s_{w,t})^\gamma+N^b\Gamma^b(s_{b,t})^\gamma}\right)(1-PR_t)Y_t
\end{aligned}
\tag{D1b}
$$

$$
\begin{aligned}
&(1+\tau_t^c)\left(\frac{p_t^h}{p_t}c_{b,t}^h+\frac{p_t^f}{p_t}c_{b,t}^f\right)+j_{b,t}+h_{b,t}\equiv\\
&\equiv(1-\tau_t^y)w_t^g\Phi_t l_{b,t}+g_{b,t}^{cov}+(1+i_t^d)\frac{p_{t-1}}{p_t}j_{b,t-1}+\frac{p_{t-1}}{p_t}h_{b,t-1}+\overline{g}_t^{tr}+\\
&+\left(\frac{\Gamma^b(s_{b,t})^\gamma}{N^k\Gamma^k(s_{k,t})^\gamma+N^w\Gamma^w(s_{w,t})^\gamma+N^b\Gamma^b(s_{b,t})^\gamma}\right)(1-PR_t)Y_t
\end{aligned}
\tag{D1c}
$$

where $0<\Phi_t<1$ quantifies the impact of covid-19 on labour supply and $g_{k,t}^{cov}$, $g_{w,t}^{cov}$, $g_{b,t}^{cov}$ represent the transfers made by the government to capital owners, private workers and public sector employees respectively. In equilibrium, we assume that $g_{k,t}^{cov}=(1-\tau_t^y)w_t^k(1-\Phi_t)l_{k,t}$, $g_{w,t}^{cov}=(1-\tau_t^y)w_t^w(1-\Phi_t)l_{w,t}$ and $g_{b,t}^{cov}=(1-\tau_t^y)w_t^g(1-\Phi_t)l_{b,t}$. This implies that the government compensates the various households for their income losses due to covid-19.

In turn, the first-order conditions with respect to labour supply become:

$$
\frac{\mu_2}{(1-l_{k,t}-s_{k,t})}=\frac{\mu_1(1-\tau_t^y)\Phi_t w_t^k}{(1+\tau_t^c)c_{k,t}}
\tag{D2a}
$$

$$\frac{\mu_2}{(1-l_{w,t}-s_{w,t})}=\frac{\mu_1(1-\tau_t^y)\Phi_t w_t^w}{(1+\tau_t^c)c_{w,t}} \tag{D2b}$$

$$\frac{\mu_2}{(1-l_{b,t}-s_{b,t})}=\frac{\mu_1(1-\tau_t^y)\Phi_t w_t^g}{(1+\tau_t^c)c_{b,t}} \tag{D2c}$$

The market-clearing conditions in the three labour markets become:

$$N^k\Phi_t l_{k,t}=N^i l_{i,t}^k=N^k l_{i,t}^k \tag{D3a}$$

$$N^w\Phi_t l_{w,t}=N^i l_{i,t}^w=N^k l_{i,t}^w \tag{D3b}$$

$$N^b\Phi_t l_{b,t}=N^g l_{g,t}=N^b l_{g,t} \tag{D3c}$$

The tax revenue function and the consolidated government budget constraint change to:

$$\begin{aligned}T_t \equiv \tau_t^c[N^k(\frac{p_t^h}{p_t}c_{k,t}^h+\frac{p_t^f}{p_t}c_{k,t}^f)+N^w(\frac{p_t^h}{p_t}c_{w,t}^h+\frac{p_t^f}{p_t}c_{w,t}^f)+\\ +N^b(\frac{p_t^h}{p_t}c_{b,t}^h+\frac{p_t^f}{p_t}c_{b,t}^f)]+\tau_t^y N^k[\frac{p_t^h}{p_t}r_t^k k_{k,t-1}+\pi_{k,t}+w_t^k\Phi_t l_{k,t}]\\ +\tau_t^y N^w w_t^w\Phi_t l_{w,t}+\tau_t^y N^b w_t^g\Phi_t l_{b,t}\end{aligned} \tag{D4}$$

$$\begin{aligned}&\overline{g}_t^{tr}+n^k\overline{g}_{k,t}^{cov}+n^w\overline{g}_{w,t}^{cov}+n^b\overline{g}_{b,t}^{cov}+(1+i_t^*)\frac{p_{t-1}}{p_t}\lambda_{t-1}^d d_{t-1}+\\ &+(1+i_t^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^g d_{t-1}+\\ &+(1+i^*)\frac{p_{t-1}^*}{p_t^*}\frac{e_t p_t^*}{p_t}\frac{p_{t-1}}{e_{t-1}p_{t-1}^*}\lambda_{t-1}^{eu} d_{t-1}+\\ &+n^b\left[w_t^g l_{g,t}^g+\frac{p_t^h}{p_t}\left(g_{g,t}^g+g_{g,t}^i\right)+\frac{p_t^f}{p_t}m_{g,t}^g\right]+\\ &+\frac{p_t^h}{p_t}\frac{\psi^g}{2}\left[\frac{\frac{e_t p_t^*}{p_t}\left(n^k f_{k,t}+\lambda_t^g d_t\right)}{\frac{p_t^h}{p_t}n^k y_{i,t}^h}-\overline{f}\right]^2 n^k y_{i,t}^h=(\lambda_t^d+\lambda_t^g+\lambda_t^{eu})d_t+\frac{T_t}{N}+\\ &+n^k h_{k,t}+n^w h_{w,t}+n^b h_{b,t}-\frac{p_{t-1}}{p_t}(n^k h_{k,t-1}+n^w h_{w,t-1}+n^b h_{b,t-1})-\\ &-n^k\left(z_{p,t}-(1+i_t^z)\frac{p_{t-1}}{p_t}z_{p,t-1}\right)+\left(TARG_t-\frac{p_{t-1}}{p_t}TARG_{t-1}\right)\end{aligned} \tag{D5}$$

Finally, in addition to the Φ_t distortion and its implications for labour supply and labour income, the only thing that changes (relative to the model used so far for the study of the debt crisis) is the treatment of public debt. In particular, we now assume that public debt is the public financing variable that adjusts residually to close the goverment's budget identity. Recall that, by contrast, during the economic adjustment program, we assumed that it was *TARGET2* liabilities that played this role with the public debt to GDP ratio set as in the data. Following usual practice, in order to ensure dynamic stability, we assume that *TARGET2* liabilites react to deviations of public debt, d_t, from its initial 2019 value, d_{2019}, according to the following feedback (Taylor-type) policy rule:

$$(TARG_t - \frac{p_{t-1}}{p_t} TARG_{t-1}) = \gamma^{TARG}(TARG_{t-1} - \frac{p_{t-2}}{p_{t-1}} TARG_{t-2}) +$$

$$+(1-\gamma^{TARG})(TARG_{2019} - \frac{p_{t-1}}{p_t} TARG_{2018}) + \gamma^d (d_t - d_{2019}) \quad \text{(D6)}$$

where $0 \leq \gamma^{TARG} \leq 1$ is an autoregressive parameter, $(TARG_{2019} - \frac{p_{t-1}}{p_t} TARG_{2018})$ is the change in *TARGET2* liabilities prior to the pandemic crisis as implied by our numerical solution in the previous sections and γ^d is a feedback fiscal policy coefficient. For our numerical simulations, we set γ^{TARG} and γ^d at 0.9 and 0.1 respectively.

The rest of the equations remain as in Appendix C above.

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